ABSTRACT

Title of Thesis:	CARING AND CATERING THE BLUE CRAB, EDUCATIONAL WETLANDS SYSTEM AT SPARROWS POINT
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The Chesapeake Bay is the largest contained waterway in the US. Its environmental problems have existed since colonial times and have worsened. Efforts have been improving its environmental and wildlife quality, creating opportunity for its current and future inhabitants. The Bay serves as a food source for its own ecosystems and inhabitants. With a decline and slow rise of aquatic populations, and global climate change, it is essential to address the water quality and population trends. The bay offers an opportunity to solve environmental problems to promote a sustainable food source and further a connection between humans and environmental systems. Cleaning water, maintaining habitat, supporting sustainable aquaculture, and creating a restaurant with public for ecotourism and education are synergistic programs that can be designed to all work together to improve the health of the bay.

CARING AND CATERING THE BLUE CRAB, EDUCATIONAL WETLANDS SYSTEM AT SPARROWS POINT

by

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Overview

The Chesapeake Bay is home to many on the East coast, whether its anticipated 20 million inhabitants realize it or not.[1] While home to numerous ecologies, species, and activities; both commercial and recreational, its geography enables life. The Chesapeake spans from New York to Virginia with all its water bodies flowing into the Atlantic Ocean. This makes it the largest estuary in the US, spanning 64,299 square feet with over 150 smaller water bodies that flow into the Chesapeake.[2] With multiple environments such as rivers, marshes, and forests, these provide an array of ecological life.

[1] Chesapeake Bay Program, "Population," Accessed November 2020, https://www.chesapeakebay.net/state/population.
[2] "Chesapeake Bay," New World Encyclopedia, February 29, 2017, Accessed October 2020, https://www.newworldencyclopedia.org/entry/Chesapeake_Bay.

Figure 1: Chesapeake Bay Basins

Source: Ren.bou, "ChesBay Basins-e1531252370325.jpg." October 1, 2019. CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:ChesBay_Basins-e1531252370325.jpg.

Pollution

The Chesapeake is no stranger to pollution. A comparison between the colonists and the Native Americans provide context to an environmentally conscious mindset. Since the colonial times, the bay has undergone excess pollution beginning with farming tobacco. Tobacco, being the primary economic export for the colonists, depleted the nutrients in the soil. By constantly farming a specific plot of land in excess, the lack of nutrients resulted in erosion of the soils and sedimentation of the waters.

Compared to the Native Americans that respectfully cultivated the land, the colonists had less respect where land was viewed as an infinite resource and would

traverse other frontiers to further their practices. The Natives did not grow harmful crops for leisure but grew multiple crops to eat. The Three Sisters, beans, squash, and corn were grown together. This synergy offered protection from external forces and did not deplete nutrients as fast as tobacco. It is inevitable for soil exhaustion to occur from any type of farming, so the Native Americans used a plot rotation system. This allows for soil recovery by growing the crops on adjacent land, allowing nutrients to recharge. This enables farming to occur again years later. The difference between the Natives and colonists are that one has a long-lasting method and looks for the long term while the other desires instant gratification. Unfortunately, the un-environmentally conscious mindset takes over and hurts the Chesapeake as time passes.

Modern Pollution

The Chesapeake is an interconnected web of ecosystems that has a synergized web of problems that developed through time. These consist of: overhunting animals for fur, deforestation for shelter and transportation, river stone for building materials, deforestation for fuel, murky water, sedimentation causing transportation difficulties, invasive plants and animals, overgrazing, scarcity of oysters, damming rivers, overfishing, air and industrial pollution, mine water flowing into the bay, algae blooms, blue crab population decline in 1922, duck population decline, wetland draining, and dead zone and dead zone size increasing.[3]

[3] "Chesapeake Bay Timeline," Bayville, Maryland Public Television, 2005, Accessed October 2020, http://bayville.thinkport.org/printables/timeline.pdf.

Some efforts were made to reduce deforestation such as abandoning farmland, allowing forests to grow back. However, that is not enough to combat all the problems that occurred throughout time and ones that persist today. Many of these issues occur for a reason, primarily for economic gain, permanence and shelter, and technological advancement. Deforestation for fuel and pouring industrial waste into the Bay does not look towards the future, only in the moment. Another sector, commercial fishing, declined due to overfishing and pollution, and that is when measures were made to protect the environment.

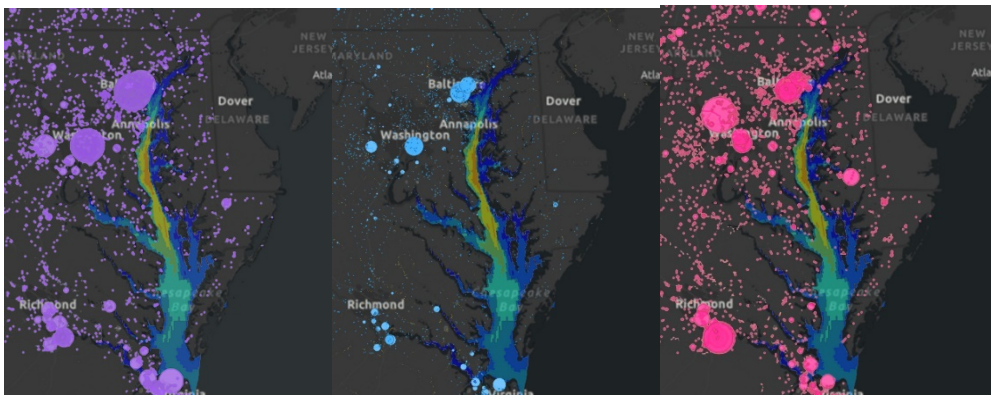

Figure 2: Nitrogen, Phosphorus, and Sedimentation Loads. Diagrams by Author.

Data From: Chesapeake Bay.net. "Waste Water Treatment Plant Loads (2018)." Chesapeake Bay Water Shed Dashboard (Beta). Accessed October 2020. https://gis.chesapeakebay.net/wip/dashboard/.

While the web of problems is evident, the main polluters of the bay today are an excess of nutrient pollution: nitrogen, fertilizer, and phosphorous.[4] Nitrogen and phosphorous exist in the natural environment, but an increase causes eutrophication. The process is where algae and plants grow due to an increase in nutrients, resulting in reduced water quality, sunlight, depletion of dissolved oxygen (hypoxia), and

[4] "What We Monitor and Why," Maryland.gov, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/waters/bay/Pages/What-and-Why-We-Monitor.aspx.

increased pH levels.[5] Eutrophication is a natural process, but humanity has sped it up. The excess nutrients result in dead zones where little life can exist, reducing the commercial and recreational activities of the bay.

Figure 3: View of the current Dead zones within the Chesapeake.

Figure 3 shows the dead zones of the bay displays where life would be alive or dead. The middle zone contains some hypoxia and waters that could be improved, but a fair amount of healthy water from the side bodies of water create a healthy environment for aquatic life to exist. However, this is only one recent point in time.

[5] Chislock, M. F., Doster, E., Zitomer, R. A. & Wilson, A. E, "Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems," *Nature Education Knowledge* 2013: 4(4):10, Accessed October 2020, https://www.nature.com/scitable/knowledge/library/eutrophication-causes-consequences-and-controls-in-aquatic-102364466/

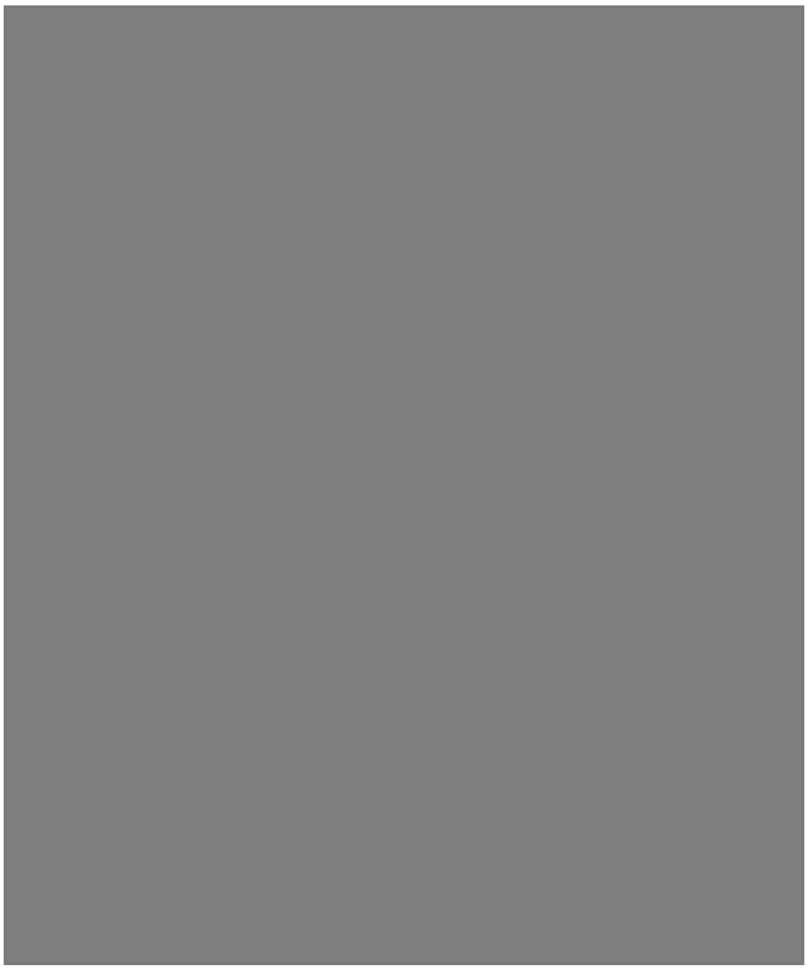

Figure 4: Hypoxic areas within the Chesapeake in August 2005

While Figure 4 excludes the neighboring rivers, the dead zone is more polluted than Figure 3. The southern Bay is has a larger yellow zone. The 2 maps paint a picture of progress but are broad. An in-depth analysis is required to understand how dissolved oxygen changes over time.

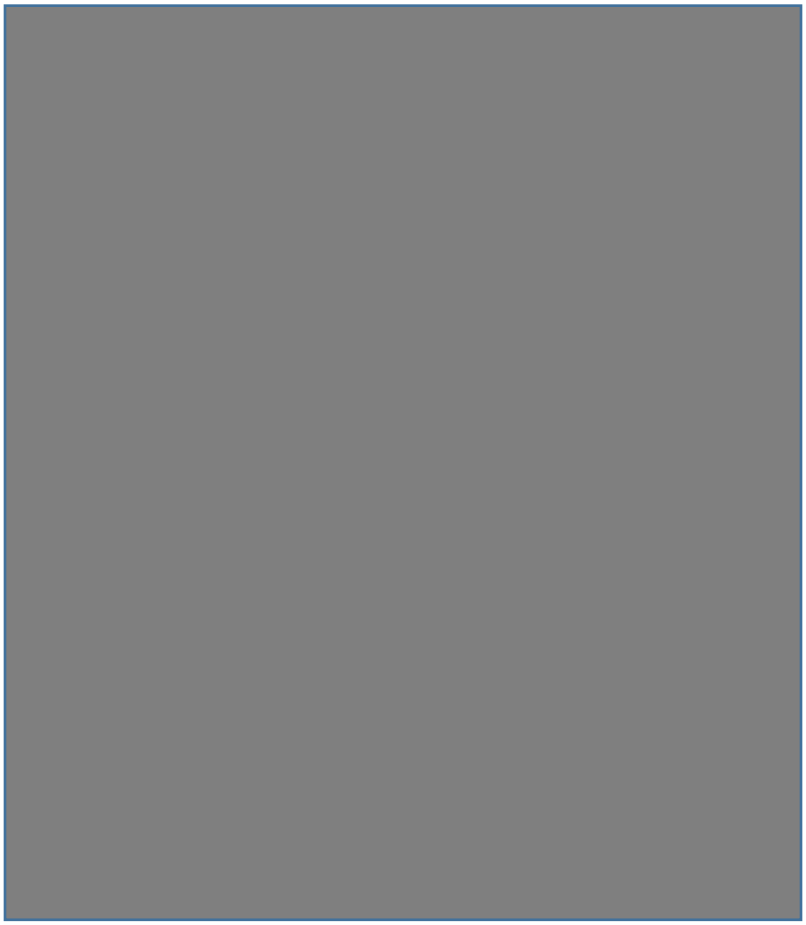

Figure 5: Dissolved Oxygen levels within the Baltimore Harbor

The chart of the dissolved oxygen levels in Baltimore contains more data. The light blue shows the range of the oxygen levels from 1984 to 2019. The blue line is the median during the same timeframe. Last, the red line represents the dissolved oxygen levels in 2020. The red line is flat from June to September, meaning no life exists. However, the winter seasons display signs of potential life. Baltimore is a harbor that contains many incoming and outgoing ships and leads into the Bay. Pollution and runoff could attribute to the lack of oxygen. Compared to the previous maps, the harbor is not as healthy as it is made out to be.

Dissolved oxygen is not the only indicator of a healthy aquatic ecosystem. Other aspects include salinity, pH, and temperature. Salinity dictates what species of plants and animals can live in an area since they rely on a particular type of water.[6] Harsh changes can result in the death of incompatible species. PH measures the acidity or alkalinity of the water, where algae blooms can occur when there is a high pH level.[7] Temperature affects the bodily processes of animals. Extreme temperature changes can prohibit and promote life in different geographies.[8] All factors are important by themselves and connected to each other.

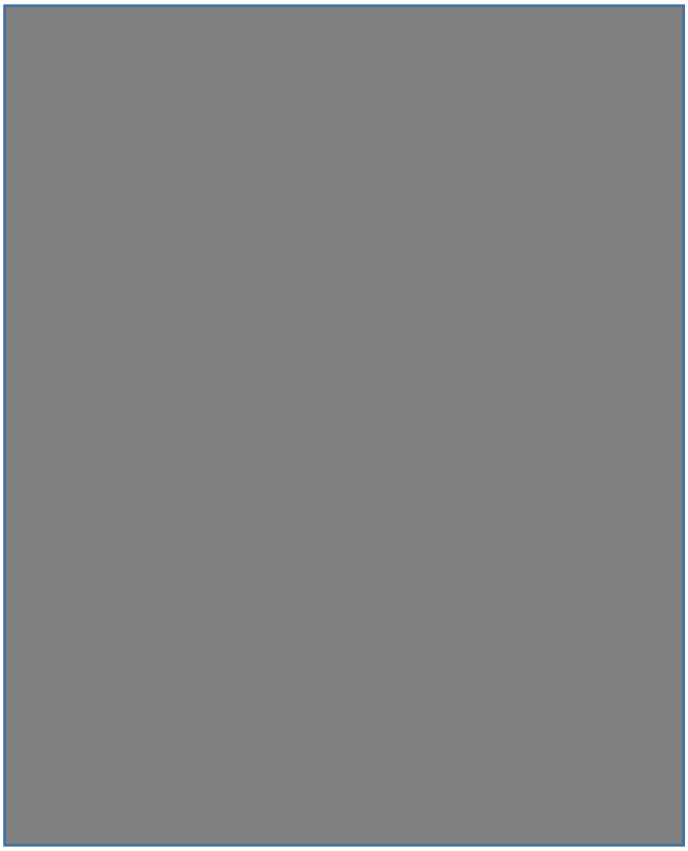

Figure 6: pH levels within the Baltimore Harbor

[6] What We Monitor and Why," Maryland.gov, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/waters/bay/Pages/What-and-Why-We-Monitor.aspx.
[7] Ibid.
[8] Ibid.

In accordance with the dead zone occurring in June to September, the pH levels contained more alkaline with levels being above 7. As the dissolved oxygen levels begin to increase after September, the pH levels begin to decrease potentially if the water is coming off an algae bloom. However, there are far more lethal pollutants in the harbor that do not cause algae blooms. The salinity and temperature levels can provide more insight to what is occurring in the harbor.

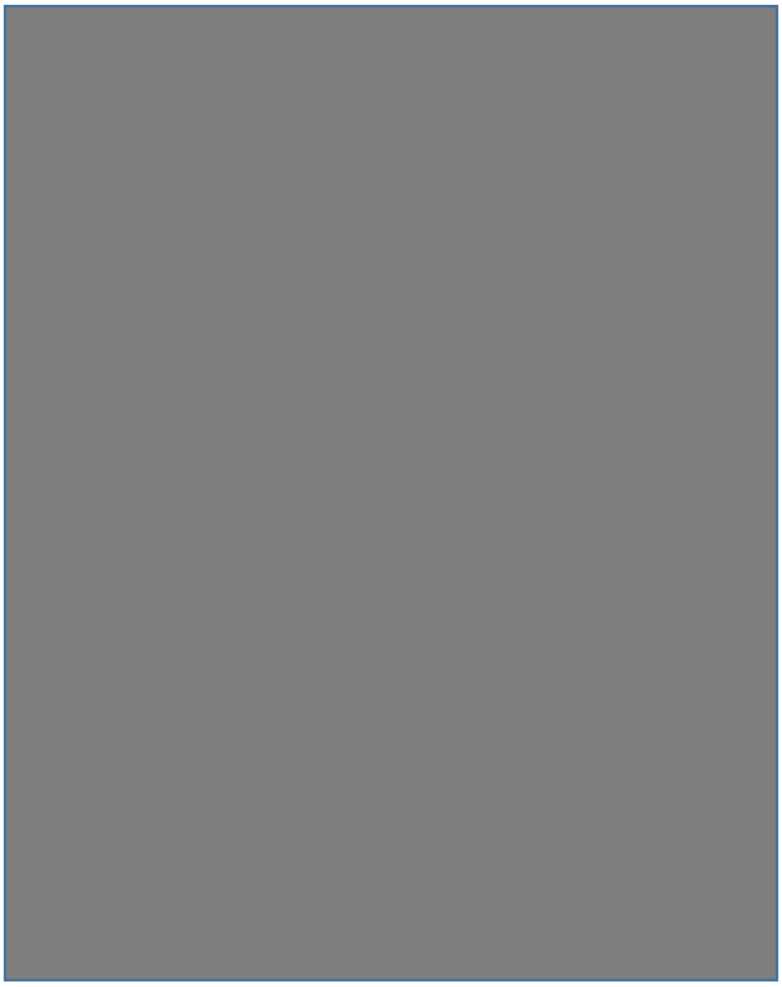

Figure 7: Salinity levels within the Baltimore Harbor

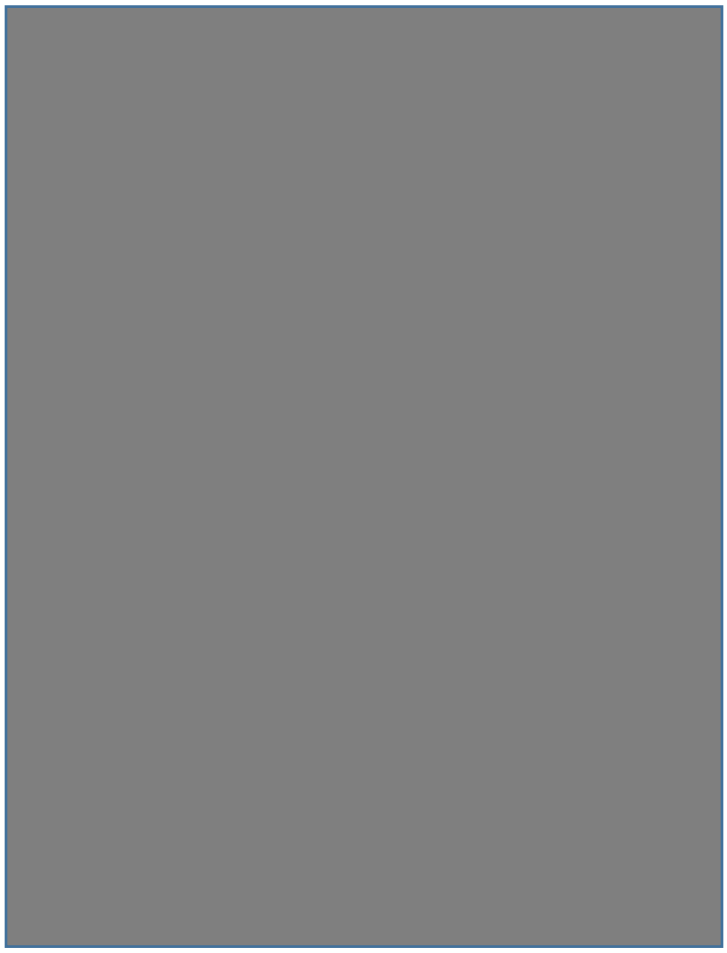

Figure 8: Temperature levels within the Baltimore Harbor

While salinity levels (Figure 7) are slightly lower than their average, there are no extreme fluctuations in the present. However, the maximums in the past have a sharp dip from January to April. Temperature does not show major fluctuations, but it does show the effects of global warming where the range has increased above the average mark more than below. The modern temperatures are also mostly above the average.

Combining all four of the measurements paints a picture of degradation in the immediate (dissolved oxygen and pH) dictating whether life can breathe underwater and being linked to algae blooms that block sunlight from aquatic life. Temperature

and salinity further supplement the previous conditions by affecting the bodily functions of species and what species can live in a particular area. This is a gradual change that furthers the absence of certain aquatic populations. The data collected has implications for those fishing recreationally or commercially, where they cannot do so during the summer.

History of Commercial Fishing in the Bay

Commercial activity has affected the Bay since the colonial times. Historically, overfishing and over-farming caused environmental issues. When the economy is impacted, measures are taken to improve the Bay's health. Technology and population spikes attribute to the increased stress of the Bay, and it began with the limitless mindset. There were no limits on anything since everything was viewed as plentiful, if not infinite. Agriculture was the main source of food during the 17th century despite the main crop being tobacco. Fishing became more important between the 17th and 18th century with how common the hook and line technology was, and all the types of fish it caught.[9] However, colonist populations increased.

18th century agricultural efforts were still the primary source, but the population grew from 35,000 inhabitants to 100,000 inhabitants by 1740.[10] More people needed to be fed requiring another food source. The 1760s saw another shift in technology with the haul seines and salt preservation, which was rare, used by George Washington and his fishery.[11] This enabled his plantation workers to be fed and have

[9] Jim Casey, "A Short History of Commercial Fishing in the Chesapeake Bay," 1, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/fisheries/Documents/history_of_comm_fishing.pdf.
[10] Ibid.
[11] Ibid.

a commercial source of income. With salt rare and costly, only commercial fisheries could use it.

The 19th century was when people noticed change in their food supply. Excessive fishing resulted in shortages of aquatic life in certain areas. This was when people began to measure the number of fish caught. In the 19th century, it was estimated that 48 million pounds of shad and 2.6 million pounds of oysters were caught, and when laws were developed to protect the species of the bay.[12] This began to set limits on the amounts, times to fish, equipment, and taxes on species.

The earliest recording of a regulation was in 1670 where people could not obstruct fish migration through dams or pots in Virginia.[13] However, the legislative efforts are not enough to stop the environmental degradation. Population increase and technology advancement inevitably outgrow a legislation This is displayed through the fishing of the blue crab.

In 1873, the refrigerator and railroad created the increase demand for crabs, and in 1878, canning furthered it.[14] Crabs were limited to the waterfront because salt did not work to preserve them, increasing the risk of spoiling when moved long distances. New technology repeats the cycle, allowing faster and further distances to be traversed. However, there was a period of less pressure on the Bay.

World War II caused a decrease in demand for fish in the Chesapeake. Efforts were focused on industry and materials needed to win the war. However, the

[12] Jim Casey, "A Short History of Commercial Fishing in the Chesapeake Bay," 1, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/fisheries/Documents/history_of_comm_fishing.pdf.
[13] Ibid.
[14] Ibid., 2.

technological advancement and return of people from the war furthered the fishing industry's capabilities.[15] New technology furthers the outgrowth of regulation and a need for more legislative protection. A 5-year period increased the number of Blue Crab caught by 10 million.[16] While the return of soldiers is good, more people fishing efficiently is not.

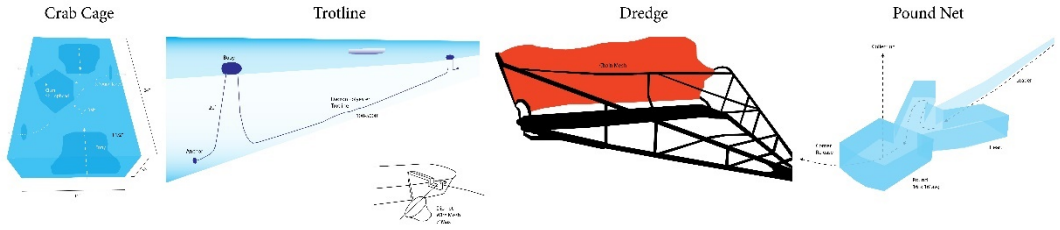

Figure 9: Commercial Crabbing Equipment. Diagram by Author

Figure 9 shows the different types of equipment used from most popular to least popular. Aside from crabbing equipment, roads and vehicles were improved during World War II. With the war over, commercial and recreational fishing conflicted with each other.[17] The same taste in aquatic life would pose the question of who gets to fish and where. Technology, access, and free time attributed to the rise in recreational fishing, but with no limits, interests were being infringed upon by both groups.

[15] Ibid., 2.
[16] Ibid., 2.
[17] Jim Casey, "A Short History of Commercial Fishing in the Chesapeake Bay," 1, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/fisheries/Documents/history_of_comm_fishing.pdf.

The Legal Battleground

Legislative action has taken place throughout the Bay's history. A brief overview will discuss many of the acts and conflicts between environmental parties. The first major act, The Clean Waters Act of 1972, contains a profound mission stated directly from the Chesapeake Bay Foundation website:

> "The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the Nation's waters."[18]

This statement is the unmistakable mission of the proceeding restoration efforts and is important in the context for future hypocrisy.

1983 is when the First Chesapeake Bay Agreement was signed between the EPA (Environmental Protection Agency), Maryland, Virginia, and Pennsylvania. While this is to guarantee cooperation, there were no goals or timeframes set.[19] This act acknowledges a problem but does not act. This is when a second and third act were signed in 1983 and 1987, respectively. The second act set measurable goals such as a 40 percent reduction in nutrient pollution by 2000, and the third is a reaffirmation of the second.[20] This is the start of major progress towards restoration of the waters, but the third act is questionable since it infers not meeting the second's goal. This preludes the modern-day EPA.

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[18] "The History of Chesapeake Bay Cleanup Efforts," Chesapeake Bay Foundation, Accessed October 2020, https://www.cbf.org/how-we-save-the-bay/chesapeake-clean-water-blueprint/the-history-of-bay-cleanup-efforts.html.

[19] Ibid.

[20] "The History of Chesapeake Bay Cleanup Efforts," Chesapeake Bay Foundation, Accessed October 2020, https://www.cbf.org/how-we-save-the-bay/chesapeake-clean-water-blueprint/the-history-of-bay-cleanup-efforts.html.

1999 is when the first lawsuit was filed against the EPA by the Chesapeake Bay Foundation for Virginia not having a TMDL (Total Maximum Daily Load) and to develop one if the state of Virginia does not by 2010.[21] A TMDL is the limit on the number of pollutants that enter the water in a day. With no limit on pollution, the waters suffer. The pattern of more metrics and specific ones needs to be measured is a reoccurring theme. Then, a fourth agreement was signed to include New York, West Virginia, and Delaware in the cleanup efforts in 2000 and remove waters from EPA's dirty list by 2010.[22] This creates the question of why these states were not included in the first one. This could be a point where the EPA realizes everything is connected and not an isolated problem per state.

2009 begins the onslaught of lawsuits for unobtained goals, primarily against the EPA. 2007 was when the EPA realized the 2000 goal was not going to be met by 2010 and was sued in 2009 for not setting a TDML for the Bay as a whole.[23] This lawsuit was eventually settled in 2010 to create frameworks for states to meet 2 year clean up goals and set a TDML. It set a limit on the phosphorous, nitrogen, and sediment that enter the waters and set a 2025 goal.[24] While setting limits is necessary for the Bay's health, it came with backlash from those that benefit from polluting the environment.

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[21] Ibid.
[22] Ibid.
[23] Ibid.
[24] "The History of Chesapeake Bay Cleanup Efforts," Chesapeake Bay Foundation, Accessed October 2020, https://www.cbf.org/how-we-save-the-bay/chesapeake-clean-water-blueprint/the-history-of-bay-cleanup-efforts.html.

In 2011, the American Farm Bureau and other partners such as the National Association of Home Builders sue the EPA.[25] They are against the limits of the pollutants entering the waters because they would have to invest and regulate their own practices. This had major implications towards the future of the Bay if the Farm Bureau won the lawsuit. However, these parties could have been included to collaborate to set limits and understand the importance of a healthy environment.

September 2013 was when the lawsuit was rejected. Only a month later, the American Farm Bureau came backed with friends; 21 Attorney Generals, to challenge the restoration efforts.[26] The Chesapeake Bay Foundation, with support from other leaders, organizations, and citizens in and out of the Bay supported the EPA. The EPA won again in 2015 because their plans were deemed logical and backed by evidence.[27]

November 2015, the Farm Bureau, friends, and more support from entities outside the Bay region go to the Supreme Court to remove the TDML and other restoration efforts. The significant action is that the Chesapeake Bay Foundation filed a counter lawsuit to this while the EPA filed a brief one.[28] The Bay Foundation is stepping up over the EPA for the EPA's legislation efforts, beginning to show the EPA not enforcing their own legislation and mission.

Between 2015 and 2020, the efforts have fallen off with the EPA not holding states accountable. Many goals were missed. In September 2020, the CBF sues the

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[25] Ibid.
[26] Ibid.
[27] Ibid.
[28] "The History of Chesapeake Bay Cleanup Efforts," Chesapeake Bay Foundation, Accessed October 2020, https://www.cbf.org/how-we-save-the-bay/chesapeake-clean-water-blueprint/the-history-of-bay-cleanup-efforts.html.

EPA, and furthers goals for 2025.[29] If the EPA no longer serves the environment, what is their purpose? They become a gateway for organizations to remove environmental protection efforts.

The holistic picture of the Bay exhibits a history of resourceful exploitation, pollution, economic explosion, and legal powers battling to prevent decimation of the Bay and its species. These forces clash today and prove how they affect Maryland's mascot, the Blue Crab.

[29] Ibid.

Chapter 2: The Blue Crab

Biology and Lifecycle

The Blue Crab, receiving its name from the color of its claws, is a prominent figure within the culture of the Bay and a figure of Maryland. While they predominantly reside in the Chesapeake, they can be found from Nova Scotia to Argentina, and live in salinity levels from 0 to 32ppt.[30] Their diets consist of any plant or animal waste, dead fish, other shellfish like oysters, and can resort to cannibalism of smaller Blue Crabs. The average size of the adult Blue crab is 9 inches, and the average lifespan is 3 years.[31] To differentiate between male and female crab, one must check their underside or apron. Males have a pointed apron while females have round aprons[32]. While their lifespan is short, their lifecycle is harsh.

Figure 10: Female (Left) and Male (Right) Apron.

[30] "Maryland Fish Facts.," Maryland.gov, Department of Natural Resources, Accessed October 2020, https://dnr.maryland.gov/fisheries/pages/Fish-Facts.aspx?fishname=Shellfish%20-%20Blue%20Crab.
[31] Ibid.
[32] Ibid.

Their lifecycle begins with the mating season from May to October in the middle of the Bay.[33] The male Blue Crab mates with the female and moves on to find other mates. The female crab travels to the lower part of the Bay to release her eggs. During this time, she develops an orange sponge containing 750,000 to 2 million eggs, where only 1 percent survive.[34] The eggs hatch into larva, and currents push them to the ocean. The ones that return, grow to a megalops, a more developed larva, and then a small "immature" blue crab. This growth takes between 1 to 1 ½ years.[35]

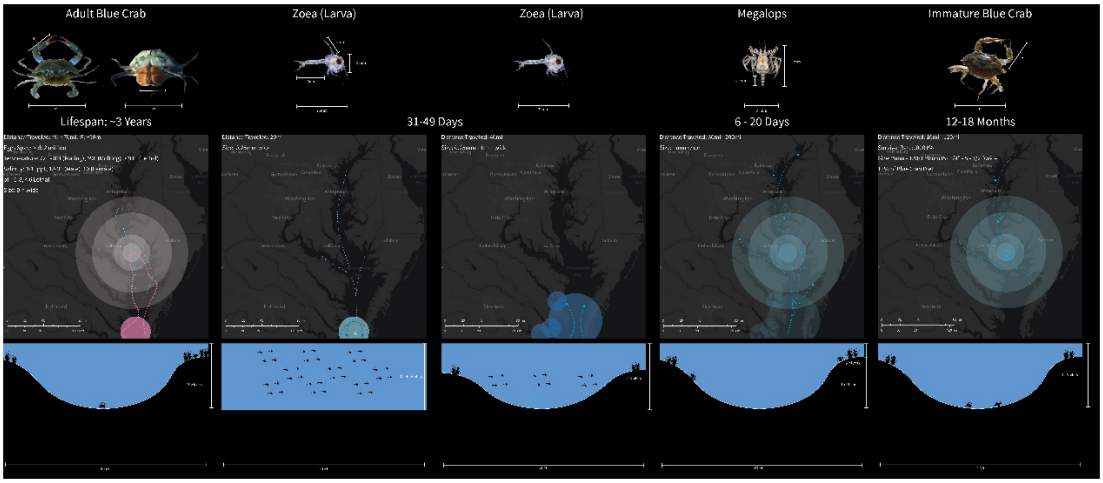

Figure 11: Crab Lifecycle. Diagram By Author.

Existing Blue crabs and the young that return reside primarily in submerged aquatic vegetation (SAV) as a habitat and nursery for the young. This also allows them to escape predators. They can live in oyster reefs too, hence a source of food. However, degradation of the water and global warming increasing the temperature reduce the number of underwater grasses, increasing the vulnerability of the Blue

[33]"Blue Crab," Chesapeake Bay Program, Accessed October 2020, https://www.chesapeakebay.net/S=0/fieldguide/critter/blue_crab .
[34] Ibid.
[35] Ibid.

Crab. In 2008, the Bay had 77,000 acres of SAV where a healthy Bay would have 185,000 acres.[36] Temperature also changes what other species can live nearby, increasing the number of predators which are larger fish and birds.

Population

Population metrics are key to providing context to an ongoing problem and provide the basis for management strategies. The Chesapeake Bay Stock Assessment Committee conducts a survey to understand the population of the Blue Crab, creating many ways of looking at the populations, trends, and factors affecting it.

Figure 12: Blue Crab Population from Dredge Survey.

Figure 12 represents the flux in population over the past 20 years. The crab populations were its lowest from 1997 to 2008. This aligns with the development of

[36] Heather Dewar, Tommy Landers, and Elizabeth Ridlington, "Watermen Blues Economic, Cultural and Community Impacts of Poor Water Quality in the Chesapeake Bay," 1, Environment Maryland, September 2009, Accessed October 2020, https://environmentmaryland.org/sites/environment/files/reports/Watermen-Blues---Environment-Maryland.pdf.

legislation from the EPA and how there were no measurable goals. Also, not every state within the Bay was committed to the restoration of its waters. Then the population spikes starting in 2008 due to the limits of pollutants allowed in the Bay, followed by lawsuits to remove the pollution limitation. The EPA's lack of holding states accountable is evident in the decline of the population in 2016. While the overall levels provide an overview, the population broken down further provides further analysis. The female Blue Crab receives more attention for its importance to population.

Figure 13: Female Blue Crab Population from Dredge Surveys.

Figure 13 displays the female population numbers and how their rises and falls dictate the overall population from figure 7. Their population rises are slightly shifted before the overall population rises. For example, 2008 is where the rise began for both the female and overall population. The drop in female crab population in 2010 correlates with the decline in overall population from 2012 to 2014, resulting in the almost horizontal line from 2013 to 2014 in overall population. In 2018, the

female crab population rose again with a rise in overall population. 2018 was also the year where restrictions for commercial and recreational fishing were lessened by a little.[37] The male populations also need analysis to see trends and create management decisions.

Figure 14: Male Blue Crab Population from Dredge Surveys.

The male population has been consistently lower than the female crab population and peaks with smaller numbers. The male population was larger than the female population in 1990 until the banning of crabbing female crabs, making the male population the primary source of crabbing. 2002 is another instance when the male population was higher than the female population, but during the period of low overall population. While the female crab population takes off in 2008, the male population slightly increases, but then reaches the low point when the female

[37] "2020 Chesapeake Bay Blue Crab Advisory Report," 7, Chesapeake Bay Stock Assessment Committee, June 22, 2020, Accessed October 2020, https://www.chesapeakebay.net/documents/2020_Blue_Crab_Advisory_Report_Final_06-22-20.pdf.

population is at an unacceptable low point in 2014. The male population being the primary food source for commercial and recreational harvesting reflects how healthy the female and overall population is.

Understanding the populations help determine actions to further protect the crab populations. General legislation helps protect the population from excessive commercial and recreational pressure, pollution, and brings together others to understand and solve problems.

Management

Generally, there are restrictions placed on female crabs and crabs that are molting. Harvesting the female crab means no reproduction and replenishment of the population. Male crabs can receive restrictions if overall numbers are low. This is essential for crab population restoration.

To manage and improve the populations of the blue crab and other species, organizations rely on different measurements of surrounding factors to narrow down the issue and areas for improvement. The previous figures are just a few ways to measure the population in detail. The document further broke down the population charts to exploited populations and other trends showing the overall flux in population. The population breakdowns are the baseline measurements for other management practices to occur.

Target numbers are a form of management to prevent overfishing along with certain legislations preventing fishing of exploitable species. According to the Chesapeake Bay Stock Assessment Committee, recreational crabbing accounts for 8

percent of crabs caught and recreational crabbing of female crabs is illegal.[38] To protect these populations, metrics are set to prevent overfishing and a tolerance for acceptable fishing populations. See figure 15.

Figure 15: Limitations on Female Crabbing

The threshold limits are the extremes that can be crabbed. Having a lower percentage means the exploitation goals have been met, exceeding the target. The abundance did not meet its minimum requirement in 2014 which correlates with the low population levels during the time (see Figure 12). While it did meet its goal in 2017, the levels remained at an acceptable rate for crabbing. More work needs to be done to reach the target. Without these measurements, it would be impossible to acknowledge the trends and make decisions to better the environment that helps the Blue Crab.

[38] "2020 Chesapeake Bay Blue Crab Advisory Report," 8, Chesapeake Bay Stock Assessment Committee, June 22, 2020, Accessed October 2020, https://www.chesapeakebay.net/documents/2020_Blue_Crab_Advisory_Report_Final_06-22-20.pdf.

Data is necessary to make decisions, but population is not the only factor in creating management strategies. Other factors surrounding the preservation efforts include the environment, the public, government, scientific knowledge, and fishing efforts. The environmental factors encompass the dynamic factors directly affecting the lives of the Blue Crab; vegetation, predators, salinity etc. Public knowledge of the matter is necessary to understand what is acceptable to catch and why.[39] By having a basic understanding, transparency can be created by understanding all the different organizations and actions implemented. People can spread awareness and further management. Government is the most necessary for the funding of projects and collaborating with different legislations.[40] Since management solutions traverse states, cooperation is required. To set limits for one area and not another would see overall declines despite one area being responsible. Scientific knowledge helps make decisions based on data like the dredge survey and understand anomalies in data.[41] Recreational and commercial fishing management emphasizes on the ability to accurately report catching. More accurate reports reduce uncertainty in data, legitimizing reports such as the Dredge Survey.[42] Licenses are also required to fish and own equipment, limiting the amount of people able to fish.

[39] "Blue Crab Abundance and Management Outcomes," 4, Chesapeake Bay Program, Accessed October 2020, https://www.chesapeakebay.net/documents/22029/2018-2019_blue_crab_management_strategy.pdf.
[40] Ibid., 4.
[41].Ibid., 4.
[42] Ibid., 9.

Economic Significance

Fishing is an important industry within the Bay. During the period of low fish populations in the early 2000s, many fisheries and multi-generational family businesses lost their jobs, having trouble pointing to where pollution was coming from.[43] While the crab populations have increased since then, there is data to prove its significance in the economy.

Figure 16: 2013- 2016 Seafood Catchings and Values.

The Chesapeake provides half of the Blue Crabs caught in the US.[44]The importance of the Blue Crab among its peers is evident in how much is caught and money generated. It is responsible for two thirds of the total commercial value and is

[43] Heather Dewar, Tommy Landers, and Elizabeth Ridlington, "Watermen Blues Economic, Cultural and Community Impacts of Poor Water Quality in the Chesapeake Bay," 23, Environment Maryland, September 2009, Accessed October 2020, https://environmentmaryland.org/sites/environment/files/reports/Watermen-Blues---Environment-Maryland.pdf.

[44] "Seafood," Maryland Manual Online, March 3, 2020, Accessed October 2020, https://msa.maryland.gov/msa/mdmanual/01glance/html/seafoodp.html.

almost the whole seafood weight caught. These numbers increase that parallel the crab populations and the years where legislation was being opposed.

The fragility, environmental, and economic importance of the crab is evident for the data being collected and initiatives to protect them. While there are many environmental factors affecting the populations, it is necessary to understand and protect the waters that support the crab.

Since the Chesapeake Bay is a complex system with a history of pollution and solutions, it is beneficial to clean up the waters for the ecosystem to continue. Humans can then continue conducting research to further restoration efforts, legislation, and then eat what is healthy. By furthering the restoration of the waters to increase the crab population, other populations that feed off the crab can be restored too.

Chapter 3: Water Treatment

Water Treatment

Water in the Bay in accordance with the TMDL requires a certain amount of phosphorus and nitrogen to be displaced. Between this and the Clean Water Act, money is granted to develop and improve wastewater treatment plants. With many types of water sources, pollutants, treatment types, site area, and water uses, it is vital to know the problem and the intended outcome.

The two primary types of water are surface and ground water. Surface water consists of the visible bodies like lakes, rivers, and oceans, while ground water is water beneath the surface.

Historically, wastewater treatment consists of two stages. The first stage removes solids by allowing massive particles such as stones sink to the bottom and let the waste turn into sludge. The second stage is where sludge is filtered and removed containing bacteria. Water is then purified with chemicals to eliminate remaining bacteria.

Figure 17: Primary Treatment

Figure 17 illustrates the primary process of turning waste into sludge, separating other solids in the grit chamber and screen. Once separated, it moves to secondary treatment.

Figure 18: Secondary Treatment

Figure 18 takes the waste past the aeration tank where it is fed through another filter. Once filtered through the chamber, it is incorporated with more bacteria that returns to the aeration chamber. The aeration tank allows for the bacteria to digest and combine with the old and incoming waste. Water is output where chemicals, prominently chlorine during this time, eliminating the remaining bacteria. Then water can be stored and distributed to the public. However, de-chlorination is required before water is being used, or UV rays can be an alternative if water is outgoing for

aquatic life.[45] These processes are the effective foundations of water treatment, but the final chemical process needed reworking to benefit aquatic life. The EPA in this document also acknowledged the future of water treatment processes and how it allows water to be cleaned for various uses.

Modern Day Treatment

Modern day treatment builds off the historic methods, but takes into consideration of the physical, biological, and chemical pollutants for treatment. While the primary and secondary processes are still used, chlorine is not the only option proceeding the initial treatments. Secondary processes can also vary.

Treatment begins with sedimentation where larger particles are deposited in a basin allowing the contaminated waters to pass on. Second was the suspended growth process but can alternate with other processes such as attached growth, wastewater lagoons, land treatment and constructed wetlands. Attached growth is like the suspended growth process but acts more as a physical filter with bacteria rather than using rock filtration. It is the most common. Lagoons act like wetlands, but are large ponds where waste eaten by organisms. Land treatment passes the pollutants through the soils to clean the wastes.

Post-secondary treatment requires disinfection, which advance from chlorine to ozone and ultraviolet treatment. Ozone shocks the waters which does not leave harmful chemicals or excess contaminants but uses large amounts of energy. Ultraviolet treatment uses light rays from mercury lamps to destroy the cells of

[45] EPA, "How Wastewater Treatment Works… The Basics," 5, May 1998, Accessed November 2020. https://www3.epa.gov/npdes/pubs/bastre.pdf.

microorganisms, which can be undone if the UV rays applied at a low intensity.[46] UV disinfection seems to be the better choice over excess chemical traces and high energy usage despite microorganisms almost being able to survive.

Other post-secondary methods can target certain pollutants, specifically nitrogen, phosphorous, and sedimentation which is useful for the Bay. As for the byproduct of water treatment, biosolids were previously dumped in the ocean, but are repurposed for fuel or fertilizer.[47] They must be treated, and their use can be limited based on the contaminants.

The implications for water treatment offer opportunities based on various configurations of treatment plants. When designing plants, it is best to plan for expansion to further the use and treatment types. The environment is everchanging and it is detrimental to be only partially effective, having the ability to clean the present and not the future. Furthering the use of biosolids is essential to treating the treatment plants as part of a larger system rather than a standalone process.

Constructed Wetlands

Pollutants ranging from organic material to petroleum and other heavy inorganic particles can be cleaned through natural processes. Constructed wetlands are a technique used both in standalone and as the final part of a treatment sequence. These are part of the natural sequence from moving from land to sea, making water accessible for plants and other organisms to use. Generally, wetlands are cheaper than

[46] EPA, "Primer for Municipal Wastewater Treatment Systems," 16. September 2004, Accessed November 2020, https://www3.epa.gov/npdes/pubs/primer.pdf
[47] Ibid., 21.

water treatment plants, require low maintenance, are receptive and can be integrated to the surrounding area. However, disadvantages consist of requiring more land, requiring water, inconsistent performance, and processes being more sensitive to toxic chemicals. Since wetlands are part of the natural habitat, fluctuations in water flows and other climatic conditions like temperature can alter performance.[48] While it is a manmade structure, it can become natural and sustain itself.

There are two types of constructed wetlands: surface and subsurface flows. Surface flow wetlands are where the water level is above ground and shallow. These wetlands are low maintenance, can provide habitat, and are for stormwater runoff, agricultural runoff, and mine drainage.[49] Since these are less intensive and shallow, they require more land. Subsurface flow systems are more intensive wetlands where water is located below ground where more intensive filtration systems occur. This system is tailored to wastewaters for all the different filtration layers being below ground, which creates safety for humans. However, its disadvantages are that it is more expensive, higher maintenance, handles less water, and can clog or have water flow to areas it is not supposed to.[50]

Comparing their disadvantages makes the argument for a water treatment plant sound more optimal. However, the systems should be combined for the most optimal efficiency. A surface flow system can absorb lighter runoff and pollutants while subsurface systems can clean heavier polluted areas. This would make

[48] United States Environmental Protection Agency, "A Handbook of Constructed Wetlands," 18, EPA.gov, October 2015, Accessed November 2020, https://www.epa.gov/sites/production/files/2015-10/documents/constructed-wetlands-handbook.pdf.
[49] Ibid., 14.
[50] Ibid.

budgeting easier by spending what is necessary to maximize performance. As for the environmental experience, humans can traverse these wetlands for recreation while providing maintenance to specific areas and learn about pollution from the concentrated subsurface wetlands.

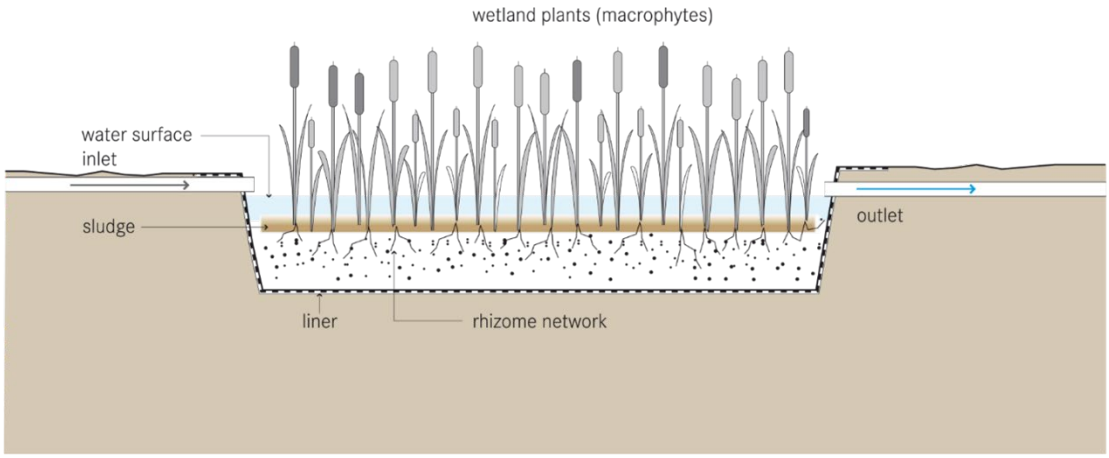

Figure 19: Basic Constructed Wetlands Diagram.

Source: Eawag: Swiss Federal Institute of Aquatic Science and TechnologyTechnical drawings: designport, Paolo Monaco, Zurich. "Free Water Surface Constructed Wetlands Diagram." See http://ecompendium.sswm.info/copyright, CC BY 3.0 <https://creativecommons.org/licenses/by/3.0>, via Wikimedia Commons. Accessed November 2020. https://upload.wikimedia.org/wikipedia/commons/f/fe/Free_Water_Surface_Constructed_Wetland_diagram.svg.

Figure 19 demonstrates the process of a subsurface flow wetlands where water enters the system and is cleaned by the vegetation above. Below is where gravel, roots, and sand extensively clean the rest of the waters. Liner prevents polluted water from entering the ground. Once enough water is clean, then it returns to the environment.

There are other factors and considerations for designing wetlands aside from their components. Seasonal change affects the flow of wetlands where too much water can enter a system excessively in the Winter and Spring, not giving the system time to clean. Summers with high evaporation cannot clean enough water which will

result in inadequate moisture for the wetlands to maintain itself, and outgoing water.[51] While wetlands handle the stresses of pollutants, too much stress on a system can also destroy biodiversity. The wetlands systems are meant to adapt over time. The more diverse it is, the more natural interactions it can have, furthering its resiliency. If there becomes a form of vegetation that is dominant, killing off other species could shorten the lifespan of the system and require human intervention to mitigate the effects.[52]

General design guidelines encourage simplicity of systems, integration of the surrounding environment, incorporation of sloped topography to promote water travel, being in vicinity of polluted waters, and is outside of the floodplain. These make for the least redundant design to solve water pollution. The more natural the process is, the higher chance for success. The more technological or overengineered it is, the greater chance for failure.[53] However, there are wetlands that are susceptible to sea level rise.

Sea Level Rise Implications for the Bay

Sea level rise is the result of global climate change where the glaciers melt, increasing the water level worldwide. This stems from the greenhouse gases creating a hole in the ozone layer, capturing heat, and increasing the Earth's temperature. While the process is inevitable, human activity increased the rate of change. The Chesapeake Bay is susceptible since it is a coastal water body, bearing harsher consequences for its systems and inhabitants.

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[51] United States Environmental Protection Agency, "A Handbook of Constructed Wetlands," 14, EPA.gov, October 2015, Accessed November 2020, https://www.epa.gov/sites/production/files/2015-10/documents/constructed-wetlands-handbook.pdf.

[52] Ibid.

[53] Ibid., 37.

Humans, plants, and animals become vulnerable from the projected 2-foot rise. For humans, they become displaced physically if their homes cannot withstand the rising tides. Furthermore, increase in storm and wave intensity creates a more destructive force, increasing human displacement. With various plants and animals, water types, and other factors influencing numerous ecosystems and cycles within the bay, change results in the loss of certain habitats. The Blackwater National Wildlife Reserve in the southern Bay is one of the susceptible areas. According to the National Wildlife Federation, 161,000 acres of brackish marshes and 29,000 acres of tidal swamps will become less ecologically diverse waters by the year 2100.[54] Less ecologic diversity prevents future adaptability. Changes in water characteristics from the first chapter will encourage the domination of certain species over others. Lands including undeveloped dry land, and ocean and estuary beaches are to decline by 167,000 acres and 58 and 69 percent, respectively.[55] Loss of dry land means the land invites more water in the soils. Loss of beaches further habitat destruction.

To mitigate sea level rise, there are 4 types of design strategies: hard protection, soft protection, store, and retreat strategies. Hard protection consists of projects like seawalls and dikes. These are the least natural methods, but the most popular for its simplicity. These are not as sustainable as other methods. The primary material is concrete, requires large amounts of land, and disrupt ecosystems and other

[54] National Wildlife Federation, "Sea-Level Rise and Coastal Habitats of the Chesapeake Bay: A Summary," 2, 2008, Accessed November 2020. https://www.nwf.org/~/media/PDFs/Global-Warming/Reports/NWF_ChesapeakeReportFINAL.ashx

[55] Ibid.

natural processes. Since developers of coastal areas have lots of money, it is possible coordinate funding and create public space to the development.[56]

Soft strategies like dunes and living shorelines offer protection through natural means. These methods promote biodiversity, further integrating and protecting the environment and ecosystems. However, these require more space to integrate with nature, and can fail from human activity. Education and recreation can be incorporated to accommodate positive human interaction.[57]

Store strategies invite water in spaces to control and mitigate flooding effects. These range from large scale techniques like flooding plazas to smaller pervious pavers that filter the water. While these can create dynamic spaces, these cost more at the larger scale and physically harm humans if it cannot hold all the water.

Retreat strategies allow for water to travel near structures and involve techniques such as higher floors and floodproofing. While this allows the natural flow of water to occur, it is extremely expensive and requires mass coordination to achieve success. This is the most long-term solution, but least used.

The Chesapeake Bay needs these strategies to revitalize its health and allow human settlement to exist. Site analysis will be required to make an assessment for what strategies are feasible and the most effective. Through these strategies will existing ecosystems and activities prevail.

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[56] Stefan, Al. 2018, "Adapting Cities to Sea Level Rise : Green and Gray Strategies. Washington, DC: Island Press," 53, http://search.ebscohost.com.proxy-um.researchport.umd.edu/login.aspx?direct=true&db=nlebk&AN=2285034&site=ehost-live .

[57] Ibid., 89.

Chapter 4: Aquaculture

Overview

The Food and Agriculture Organization (FAO) defines aquaculture as

> "…the farming of aquatic organisms, including fish, mollusks, crustaceans and aquatic plants. Farming implies some form of intervention in the rearing process to enhance production, such as regular stocking, feeding, protection from predators, etc. …while aquatic organisms which are exploitable by the public as a common property resources, with or without appropriate licenses, are the harvest of fisheries."[58]

Aquaculture is the synthesis of agriculture and aquatic species. While this practice has existed for centuries, it gained prominence where it is responsible for a large portion of the food supply and is responsible for half of the world's seafood supply.[59] It is most common in countries outside the United States and historically the response to an increased demand for sea food.

There are many dimensions surrounding aquaculture and its environmental and social implications. Aquaculture requires water for habitats and fisheries. Large amounts of water can be used depending on the scale. Since aquaculture is a

[58] Food and Agriculture Organization of the United Nations, *Introduction to Aquaculture*, April 1987, http://www.fao.org/3/x6941e/x6941e04.htm#bm04.1

[59] Trushenski, Jesse T, *Understanding Aquaculture*, Sheffield, United Kingdom: 5M Publishing, 2019, 12, http://web.a.ebscohost.com.proxy-um.researchport.umd.edu/ehost/ebookviewer/ebook/bmxlYmtfXzIxMzUxODhfX0FO0?sid=18214a0f-264b-4abf-be49-a67a04fe9867@sdc-v-sessmgr01&vid=0&format=EB&rid=1

production, it will create waste which poses the question of how to dispose or use it. Furthermore, environmental groups and commercial fishing industries oppose this practice and collaborate for being in competition with the industries and allegedly damaging ecosystems.[60] While aquaculture has implications for the environment and vice versa, the impacts can be more beneficial.

Methods

Aside from the salt and freshwater, there are many different aquaculture systems based on being intensive or extensive. Extensive aquaculture permits the use of engaging with the natural environment, allowing it to perform like a natural ecosystem. Intensive focuses on industrializing the farming of aquatic species through their production, increasing and isolating methods. Because extensive aquaculture is to be "natural", it requires large amounts of land and is susceptible to pollution and other environmental conditions. Intensive compacts the area of the process but uses resources at a higher rate.

[60] Trushenski, Jesse T, *Understanding Aquaculture*, Sheffield, United Kingdom: 5M Publishing, 2019, 43, http://web.a.ebscohost.com.proxy-um.researchport.umd.edu/ehost/ebookviewer/ebook/bmxlYmtfXzIxMzUxODhfX0FO0?sid=18214a0f-264b-4abf-be49-a67a04fe9867@sdc-v-sessmgr01&vid=0&format=EB&rid=1

Figure 20: Cage System

Source: Thomas Bjørkan, "Fish Cages." CC BY-SA 3.0.<https://creativecommons.org/licenses/by-sa/3.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Fish_cages.jpg

The cage system is an intensive system where fish are isolated from the environment to maximize production. This method is cheap and replicable regardless of water type and space, but its density invites problems. The density limits production and allows for the spread of bacteria and disease to travel faster leading to high death rates.[61] The more fish in the water, the lower the oxygen, almost creating a dead zone, resulting in the limit before the waters cannot withstand the fish. With the system being out in the open, some predators can enter reducing the stock. The closed loop system also requires the fish to be fed to since they cannot leave their waters.

[61] Michael Masser, "What is Cage Culture?," Southern Regional Aquaculture Center, 160, July 2008, Accessed November 2020, http://agrilife.org/fisheries2/files/2013/09/SRAC-Publication-No.-160-What-is-Cage-Culture.pdf

Figure 21: Integrated Recycling System

Integrated recycling aquaculture systems are intensive closed loop systems that maximize efficiency. The components of the system consist of the fish tank, mechanical filtration, pump, and biofiltration to return to the fish tank. The reuse of up to 90 percent of water and waste removal reduces resource consumption.[62] The filtrations further the quality of water, reducing disease that would exist in cage systems. The sizing of the system does not take much land either, making it a compact option for urban environments. However, its drawbacks are it requires water, electricity, food, and highly trained staff.[63] It is a closed loop system, but entropy is

[62] Aquaculture ID, "Recirculating Aquaculture System," Accessed November 2020, https://www.aquacultureid.com/recirculating-aquaculture-system/#
[63] Aquaculture ID, "Recirculating Aquaculture System," Accessed November 2020, https://www.aquacultureid.com/recirculating-aquaculture-system/#

present. Water evaporates requiring replenishment. The need for electricity is required to run the system all day and night. While this is a more expensive system, it tries to minimize its impact compared to the cage system. The integrated system can be furthered to synergize with the waste products by incorporating hydroponics with the fish, making the system more extensive.

Figure 22: Pond System

Source: Faintsmoke," Pond for breeding young fish Aquaculture Research and Development Centre, Kajjansi." CC BY-SA 4.0 <https://creativecommons.org/licenses/by-sa/4.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Pond_for_breeding_young_fish_Aquaculture_Research_and_Development_Centre,_Kajjansi.JPG

The pond system is a primarily extensive system that allows a single type of fish or multiple species to grow together. The pond can be integrated with the natural environment if impacts can be mitigated. While this creates a wholistic opportunity, waste needs to be addressed or it can cause further degradation of the environment.

Depending on the location, water use needs to be efficient to prevent resource loss, making the system more intensive.[64] If not, it can be detrimental to the environment.

What is beneficial from these systems aside from polyculture, is the byproducts that are produced. The byproduct is the waste of one process that can be used in another. The East Kolkata Wetlands of India exemplify the synergies among systems. The systems combine farming, wastewater treatment, and aquaculture while using the byproducts to further another aspect of the system. It treats water that promotes algae and duckweed growth to be used for fish food, and the water from fish have increased nitrogen and phosphorous levels used for growing rice patties.[65] Nothing is wasted, creating the most efficient system. The crops and fish are also sold nearby, cutting transportation emissions. Since this is a pond system, it is still susceptible to outside environmental degradation.

Chesapeake Bay Aquaculture

The Chesapeake deals with aquatic population problems along with a food supply demand. Historically, oysters have been the lowest population from overfishing and environmental degradation. Both intensive and extensive methods are being used to revitalize the population and environment.

[64] FAO, Aquaculture In the Third Millennium, Accessed November 2020, http://www.fao.org/3/AB412E/ab412e07.htm

[65] Ezban, Michael, *Aquaculture Landscapes : Fish Farming and the Public Realm.* Milton Park, Abingdon, Oxon: Routledge, 2020, 133.

Figure 23: Floating Oyster Cage

Figure 24: Submerged Oyster Cage

Intensively, oyster cages are either floating or submerged. Floating cages have less density than the submerged cage. While caged aquaculture systems contribute to

environmental pollution, the oysters can help clean the environment. The oysters can remove nitrogen and phosphorous based on the number and size.[66]

Alternatively, extensive oyster aquaculture involves the restoration of the oyster reefs. While continuing to clean the waters, oyster reefs further biodiversity. This allows for other grasses and species of fish to exist in a wholistic ecosystem. The excess fish can be harvested with oysters.

Blue Crab Hatchery

When the Blue Crab population of the Chesapeake Bay was low, the idea to create a Blue Crab hatchery in Mississippi occurred. While the hatchery is a closed and intensive system, it is set in 3 stages based on the crab life cycle where it goes from tank, to raceway, to ponds to allow recreational crabbing.[67] The tanks are fed with brackish waters, are monitored, and can alter the pH, temperature, and other factors to optimize the environment. The importance of the female crab is exemplified where one molting female crab populates the system. At the end of the system, molting blue crabs are taken to further continue the process.

Having a mixed program is more humane in the final stage giving the adult crab an environment. The earlier stages resemble cage systems, but with a high density in a tank and raceways instead of open waters. However, the density problem furthers cannibalism which reduces stock and defeats the purpose of the hatchery.

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[66] Kellogg, Lisa, Jessica Turner, and Grace Massey, "Environmental and Ecological Benefits and Impacts of Oyster Aquaculture," Virginia Institute of Marine Science, June 27, 2018, 18, https://www.nature.org/content/dam/tnc/nature/en/documents/TNC-Aquaculture-Final-Report_062818.pdf

[67] Waycott, Bonnie. "Research project showing potential for farming Blue crab." Aquaculture North America. June 15, 2019. https://www.aquaculturenorthamerica.com/research-project-showing-potential-for-farming-blue-crab-2383/.

The raceways expand the crab space when transitioning from the larval stage in a 1000-liter tank to a megalope in a 6' x 22' area with structures that shelter them.[68] This helps with cannibalism reduction but does not stop it.

While this process is developmental, its intentions can diversify the farmer's economy and environment, and transfer the process along the Atlantic.[69] While the system is currently closed, it has intensions of opening. Having crabs can be an income source on its own when fishing conditions are not optimal. It can be used to attract other fish species that the farmer can farm and create biodiversity. If this method spread throughout the Bay, it would increase the crab population without having to worry about regulations or extreme environmental conditions. Resource use would need to be measured since it is a closed system.

There are many different forms and methods of aquaculture. Having the public engage with the process can further spread awareness of the practice. While the most environmentally friendly types do not have the highest production rate and require the most land, they can provide the most benefit in the long term. By engaging with the natural environment, the system can offer more habitat and integrate with the local ecosystem. When designing the system, the question of where, what species it is for, and what other systems will it incorporate with will dictate its extents. And the product will be delicious.

[68] Ibid.
[69] Ibid.

Chapter 5: Seafood Restaurants

Local Vs Imported Seafood

Food is an essential element to every culture. Cuisine, locally and globally, defines regions and is part of the tourism experience. Because everyone needs to eat, knowing where and what furthers the decision making of both the tourist and local. The popularity of a dish is based on a culture's customs and how tourists receive it. Whether it is wine, fish, pasta, etc., it is important where it comes from and how it was prepared to create a safe and authentic experience.

At the global scale, seafood does not dominate people's diets. It accounts for only 21.3% of protein in China, 22.6% in Japan, and 14.3% in Norway in 2011.[70] Seafood has more opportunity to be incorporated and it is beneficial to have a varied diet to maintain optimal health. Despite the United States importing most of its seafood, they eat less than the rest of the world.

It is important to know where one's food comes from. Local sources are more sustainable since they reduce transportation distance and come from a local ecosystem and environment. Reduced distance lessens emissions and taking from a local ecosystem will not cause environmental change, assuming the source is not over fished. Commercial fishing can be more sustainable if guidelines and science-based restrictions are followed despite commercial fishing and unregulated fishing contributing to the decline of aquatic populations.

[70]Philip A. Loring, S. Craig Gerlach, and Hannah L. Harrison, "Seafood As Local Food: Food Security and Locally Caught Seafood on Alaska's Kenai Peninsula," *Journal of Agriculture, Food Systems, and Community Development 3,* (2018): 15, doi:10.5304/jafscd.2013.033.006.

Imported seafood is the opposite where large amounts of fish are transported over long distances. Despite a large portion of the United States population lives on the coast, the United States imports over 80 percent of its seafood according to the NOAA fisheries.[71] These sources are primarily located in Asia and South America which generate more emissions.

The specifics of the United State's seafood imports and exports in 2018 was 22.4 Billion dollars and 2.7 million tons imported and 5.2 Billion dollars and 1.3 million tons exported.[72] It would be economically beneficial and more sustainable to eat the exports rather than accumulate a 16 billion dollar deficit from importing seafood. Unless the intrinsic value or demand of eating foods such as shrimp, salmon, and tuna are better as imports than fishing those within our waters, it is redundant. If we cannot fish those within our waters because of pollution or overfishing, then it is a sign of needed change. Furthermore, the United States imports 380,000 tons of salmon costing 3.9 billion while exporting 145,000 tons costing 783 million dollars in 2018.[73] Again, a net loss in profit by importing something local that cannot be exported at the same rate.

While the United States imports more seafood than it exports, it has been this way since 1941 where exports were valued at 22 thousand dollars and 97 thousand tons compared to importing 40 thousand dollars and 138 thousand tons.[74] There has never been a positive profit overall or in individual categories of edible and non-

[71] Fishwatch, "Global Wild Fisheries," Accessed December 2020, https://www.fishwatch.gov/sustainable-seafood/the-global-picture
[72] NOAA Fisheries, "Imports and Exports of Fishery Products Annual Summary, 2018," NOAA, Last updated July 16, 2019, 1, https://www.st.nmfs.noaa.gov/Assets/commercial/trade/Trade2018.pdf
[73] Ibid.
[74] Ibid., 27.

edible products. It poses the question if the United States can leave the system that is draining money. Unless the exports cannot meet the local seafood demand, and not people wanting certain types, it would be beneficial to live with what the United States can fish.

Slow Food

Industrialization has sped up the food making process and changed the pace of life. The fast pace of life created the notion of being able to access anything at any time. While resources are renewable, they are finite within a certain time depending on how fast they are consumed. Applying sustainable lessons, such as the triple bottom line, to protect local cuisine and ecology, The Slow Food Movement was created in 1989 to reapproach agriculture. Its triple bottom line is good, clean, and fair which is about the quality of food, making every stage of the production process protect the health of the consumer and environment, and be able to make a profit while respecting culture.[75] It is a complex system that tries to integrate everyone in the agricultural process. The Slow Food cites the farmer Wendell Berry about eating being an agricultural act.[76] By considering eating and agriculture as one, the consumer and producer become intertwined. General sustainability education can make people more aware of how they can help the environment. The same is for the consumer learning about the food they eat, collaborating with the producer.

[75] Slow Food, "Good, Clean and Fair: the Slow Food Manifesto for Quality," SlowFood, August 2015, 1 https://www.slowfood.com/wp-content/uploads/2015/07/Manifesto_Quality_ENG.pdf.
[76] Ibid.

In Columbia and Mexico, a slow fish movement was designed to protect the Black Crab and Caribbean Spiny Lobster. The Black Crab and its sustainable consumption were spread to local people. They created cultural events for the community, engaged in biodiversity by producing fruits and vegetables to reduce the pressure on the Black Crab, and created sustainable tourism through using an invasive species for jewelry.[77] This is a wholistic process that involves everyone in and out of the community. 9600 spiny lobsters were given a scanning system that detailed the boat that caught them, who the fishers were, date of catching, zone, biology and more.[78] This gives measurement and transparency which can be used to benefit the species, producers, and consumers. This information and approach could benefit the Chesapeake through measurement and integration of various communities. However, the difficulty of applying Slow Food to the Chesapeake would stem from its already heavily industrial and commercialized way of living, separating the consumer and producer. However, there are tourist programs that show an appreciation for food.

Seafood Cultures

Amalfi Coast is a prominent tourist location and UNESCO world heritage site in Italy, characterized by its mountains being close to the water. These mountains are dominated by the lemon which is used to make limoncello and other dishes. Some of the most used seafood are shrimp, redfish, pezzeogne, bream, sea urchins, octopus,

[77] Slow Food Foundation for Biodiversity, "Annual Report 2019," Slow Food, September 2020, 61, https://www.slowfood.com/wp-content/uploads/2020/10/ENG_annual_report_SF_internazionale_2019.pdf
[78] Ibid.

blue fish, mollusks, and anchovies.[79] These are combined with pastas to create the flavor from this region. While seafood is very prominent, illegal harvesting occurs. It brings in 2 million euros yearly and has enabled the jellyfish population to be overpopulated compared to other species.[80] This is synonymous to excess algae blooms, but not as hazardous to the environment. However, jellyfish do intrude on the tourist experience when they are in the waters.

Aside from seafood, agritourism can benefit the landscape and the people that work there. Lemons, olives, and grape cultivation has existed since the Medieval times, and protects the region from erosion and flooding.[81] By having tourists train to farm these crops, the farmers can stay in business and protect the land. The slow food movement also influenced a weeklong culinary tour with cooking classes and visiting locations along Amalfi, learning about the culture and handling ingredients such as cheese, lemon, and olives.[82] This can further the connection between tourist and location.

Another prominent seafood culture is New Orleans, with its extensive history and multiple cultures such as Cajun, Creole, French, Spanish, and more contributing to its cuisine. One of the most popular dishes is Gumbo that takes on many forms depending where in Louisiana it is made. Gumbo z'herbes consists of vegetables such

[79] Camilla (Postiano.com team), "Flavors and Aromas of the Amalfi Coast," Accessed December 2020, https://www.positano.com/en/e/flavors-and-aromas-of-the-amalfi-coast
[80] Walks of Italy, "Eating Fish in Italy: What you Need to Know," May 2, 2012, Accessed December 2020, https://www.walksofitaly.com/blog/food-and-wine/sustainable-seafood-in-europe
[81] Catherine Mack, "Responsible Tourism on the Amalfi Coast," Responsible Travel, Accessed December 2020, https://www.responsiblevacation.com/vacations/amalfi-coast/travel-guide/responsible-tourism-on-the-amalfi-coast
[82] Cooking Vacations, "Artisan Cooking Positano On The Amalfi Coast ~ 8 Day," Tour, Accessed December 2020, https://www.cooking-vacations.com/tour/artisan-cooking-positano-amalfi-coast/

as spinach and mustard greens, and meat in a pot, originating from West Africa and being eaten on Holy Thursday.[83] Food is culture, shown through the distance traveled to New Orleans and that it furthers the Catholic faith of its residents. Gumbo can also be made with sausage, okra, squirrel and duck, and potato salad. Sausage is southern gumbo, okra is coastal gumbo, squirrel and duck is from a hunter in the family, and potato salad has German influence.[84] Multiple transformations illustrate how extensive the culture is through only one dish.

There are other dishes too such as turtle soup, oyster sandwich, and shrimp remoulade. Each have their own story. Turtle soup almost caused the extinction of turtles in the Louisiana area, oyster sandwiches are from 60 percent of the nation's oyster harvest, and shrimp remoulade is about the transformation of a French dish.[85] Stories further the meaning of food within culture.

As for the Chesapeake, it has many restaurants and cultures from the water's edge to deep in the urban fabric. Acquiring local food sources is good from an emissions standpoint, but not healthy if the water is polluted.

[83] Clarissa Wei, "An Illustrated History of New Orleans Food," First We Feast, April 27, 2015, accessed December 2020, https://firstwefeast.com/eat/2015/04/illustrated-history-of-new-orleans-food
[84]Maida Owens, "Louisiana's Food Traditions: An Insiders Guide," Folklife in Louisiana, Accessed December 2020, http://www.louisianafolklife.org/LT/CSE/creole_food_trad.html
[85] Clarissa Wei, "An Illustrated History of New Orleans Food," First We Feast, April 27, 2015, accessed December 2020, https://firstwefeast.com/eat/2015/04/illustrated-history-of-new-orleans-food

Figure 25: Washington State Fish Advisory Guide

While this is Washington State's fish advisory guide, it can be applied to many other areas, especially Baltimore's waters containing PCBs.

Aside from local pollution, the United States has higher seafood regulations than foreign countries. However, tracing seafood is harder the further the distance, resulting in mislabeling of food. Mislabeling can cause food to be advertised and switched, eating a potentially more harmful food. 26 percent of seafood restaurants in the DC area had mislabeled fish.[86] This could have harmful effects depending on the type of fish and have the customers pay for something they did not want.

[86]Lauren Peltier, "Buying Safe Seafood in Baltimore's Fishbowl," Baltimore Fishbowl, October 15, 2014, Accessed December 2020, https://baltimorefishbowl.com/stories/buyingseafoodinbmoresfishbowl/

Ecotourism

Maryland has trails to experience eating Blue Crabs and oysters and have boat tours to experience different Bay aspects. Ecotourism allows for visitors to experience the environment in an educational manner. By touring a hatchery or landscape, the experience would be more meaningful in the context of environmental restoration.

The 7 benefits of ecotourism are traveling to natural destinations, environmental awareness, respecting local culture, income for conservation, income for local residents, supports human rights movements, and impacts the environment minimally.[87] Compared to normal tourism, ecotourism can be seen as an extensive process where it is not about the tourist, but about the location. The tourists provide for the environment by generating capital and spreading the popularity of a location. More people will visit, ensuring the environment has more resources.

However, ecotourism brings development, air, noise, water, and waste pollution.[88] At the global scale, the attraction and transportation of people, mainly by plane, causes increased CO2 emissions. With more people wanting to visit, air traffic increases. Between increased air traffic and number of tourists, the environment becomes noisy for both residents and nature. More tourists stress the environment by causing waste to enter the waters. Economically, tourism is a risk since it could not generate revenue if the site is not popular enough. To attempt to bring more tourists,

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[87] Jennifer Hill, and Tim Gale. *Ecotourism and Environmental Sustainability : Principles and Practice.* Farnham, England: Ashgate, 2009, 227, Accessed November 2020. http://web.b.ebscohost.com.proxy-um.researchport.umd.edu/ehost/ebookviewer/ebook/bmxlYmtfXzI5MjQ1N19fQU41?sid=dce329cf-2f60-48d3-a022-7be27df4fc2d@pdc-v-sessmgr05&vid=0&format=EB&rid=1

[88] Ibid., 20.

development of these lands destroys the natural elements and authenticity of the location.

Agritourism

There are many types of ecotourism programs such as agritourism and community development that offer an integrated experience with the environment and local culture. Agritourism extends agricultural endeavors to accommodate a wider range of activities that diversifies income. Since there are many activities that can occur within agritourism, the definition can vary. While this is a developing business strategy, it offers an experience away from standard tourism while extending local culture with outsiders.

The conundrum of agritourism is that it can be inauthentic, created only for capital gain rather than extending a lifestyle to an experience. The act of creative destruction persists since it is economically viable, converting assets on farms to accommodate more people or staging farm work to look authentic.[89] This creates a range of variables to understand the type of experience since this industry is new and does not have consistent regulations. These variables are the program being located on a working farm, degree of contact between tourist, nature, and agriculture, and the authenticity of the experience.[90] Being on a working farm dictates whether one stays and works to benefit the community and family hosting, rather staying on a farm to be within the vicinity of nature. Then, the degree of contact determines the activities one

[89] Irma Potocnik Slavic & Serge Schmitz, "Farm Tourism Across Europe," European Countryside. 5. (2013): 267 DOI: 10.2478/euco-2013-0017.
[90] Ibid.

performs. These can be just having walks with nature or gastronomic programs (tasting foods) to picking crops and other educationally active programs. Finally, authenticity determines how cultural or commercial the experience is. Because of the economic incentive, agritourism programs lean towards the commercialization which lessens connections towards nature.

Apulia, Italy, has 357 agritourism farms where 201 farms perform other activities, 11 which are educational, and allows for commercial and authentic agritourism to intersect.[91] While maximizing cultural gain would be the most beneficial to a community, having a balance of increased income can further other endeavors. In Slovenia, agritourism accommodates different ages which initially benefitted the farms. However, legal implications influenced farms to accommodate more supplementary activities such as farm demonstrations rather than more space for tourists.[92] Agritourism must be a supplementary activity by law, leaning towards commercialization. Last, Bliesgau, Germany is a UNESCO reserve that is protecting natural land, providing development guidelines around the area, and turning the area into a commodity.[93] Guidelines and protection are key to preventing environmental degradation. The commoditization of the area stems from the lack of farms, meaning the only activities are not authentic to the experience.

Agritourism is good for connecting people to the environment. While its range of activities determine the connections one will make to the culture and environment, it is devastating and evident that eventually they turn commercial. It is beneficial for

[91] Ibid., 269.
[92] Ibid.
[93] Ibid., 270.

local communities to generate capital by utilizing other areas of their business, but not at the cost of authenticity and local culture that their business provides.

Chapter 6: Site Analysis

Site Selection and Analysis

The Chesapeake Bay's water problems need to be solved with a site close to the water. Site criteria was based primarily on dissolved oxygen levels that create dead zones, the blue crab existing in those locations, the site being part of the Land Restoration Program, lack of existing restoration zones, and connectivity to the site. This should be to rejuvenate a heavily polluted area rather than improve a healthy one. LRP sites contain petroleum and metals within the soils, making it an opportunity for land and water restoration. Secondary criteria included zones of harvesting, submerged aquatic vegetation, and restriction zones. This criterion is about who can use the sites once they have been sanitized. This resulted in 5 sites.

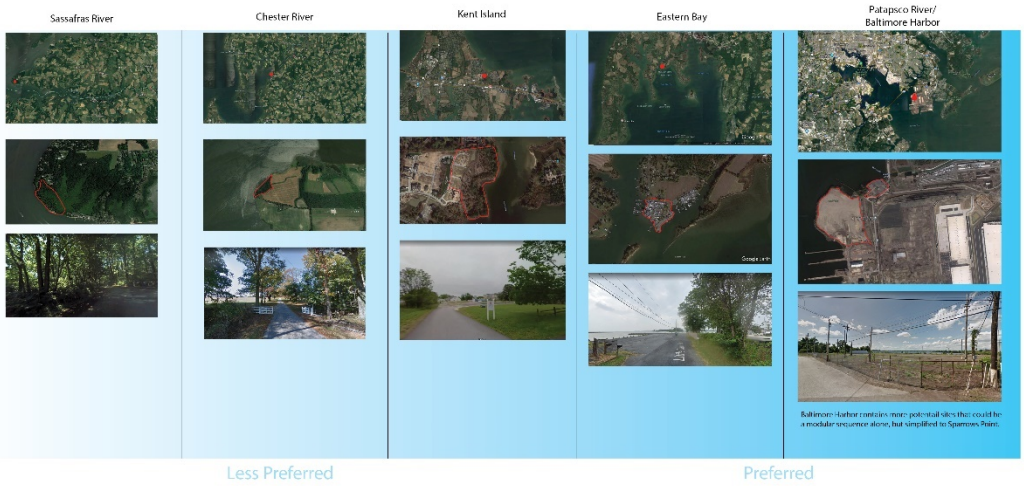

Figure 26: Site Selection. Diagram by Author.

The 5 sites are the Sassafras River, Chester River, Kent Island, Eastern Bay, and Patapsco River. While all sites contain dead zones and the blue crab, the less preferred sites had existing restoration zones, harvest zones, and submerged aquatic vegetation. This meant that these were already semi-usable.

The Patapsco River became the most preferred for how polluted it is. Aside from the water quality, the area is restricted from harvesting and had no submerged aquatic vegetation. There is only one restoration zone which is an oyster sanctuary, making it evident the water pollution is great. Being within the Baltimore Harbor, an urban location and center, it has greater access, allowing for more people to visit rather than the other rural sites. While there are many locations within Baltimore Harbor, this landed us at Sparrows Point.

Figure 27: Sparrows Point.

Source: Kubina, Jeff from the milky way galaxy. “Sparrows Point Steel Plant.jpg.” CC BY-SA 2.0 <https://creativecommons.org/licenses/by-sa/2.0>, via Wikimedia Commons. https://commons.wikimedia.org/wiki/File:Sparrows_Point_Steel_Plant.jpg

Sparrows Point was once an industrial powerhouse located at the mouth of the Patapsco River. In 1887, the area was a place for importing materials, a place for the

Maryland Steel Company, and a place for shipbuilding in 1891.[94] The historical industrial site had many health issues, work related deaths, and eventual regulations from dealing with toxic materials such as asbestos. It also led to air quality reduction and contamination of the nearby waters with pollutants such as lead, chromium, zinc, and benzene.[95] However, it created a community of workers that were proud of their efforts and creations. Overtime, the US would start outsourcing industrial work to other countries. On March 31, 2002, the company declared bankruptcy after a change in CEO, beginning to downsize and eliminate the workers' benefits.[96] The company was liquidated and passed around to foreign owners. Over time, workers were laid off until there was no one left. Demolition occurred in 2014.[97]

The tragic decline of Sparrows Point and parallels the decline of the Bay's health. The workers are used up until they are not needed anymore by the larger corporations just as the environment was used for enjoyment and development. However, humanity realizes the importance for the environment and species like the Blue Crab which is why there are restoration programs set. By restoring Sparrows Point through the means of food and the environment, it can offer a cultural rejuvenation through sustainable means. To understand the site, a SWOT analysis was conducted.

Strengths

[94]Bill Barry, "The History of Sparrows Point: An Epic Civilization," Historical Society of Baltimore, February 12, 2017, 5-10, https://www.hsobc.org/wp-content/uploads/2017/02/Sparrows-Point.pdf.
[95] Ibid., 120.
[96] Ibid., 149-152.
[97] Ibid., 188.

Sparrows Point is located at the mouth of the Patapsco River meeting the rest of the Chesapeake, acting as a gateway between the waters. Along its North edge extending West across the Patapsco is Route 695, allowing access for high volumes of traffic. Also, West in the Patapsco, is the Fort Carroll landing dock and oyster sanctuary that is a staple in environmental consciousness.

Weaknesses

Its biggest weakness is its location in Baltimore. Because of its use and location, it is outside of the boundary, this causes less attention and is not included with data documented in Baltimore. Adjacent to the site are warehouses and other industrial buildings. There are neighborhoods to the East that are a distance away, and none to the North. Finally, there are not that many areas containing a high population nearby.

Opportunities

The site being part of the LRP will rejuvenate polluted land rather than develop something new. The poor water quality is an opportunity to begin to clean the harbor's waters, allowing for more aquatic life to exist. By creating a destination for people to visit, the site can gain recognition to be a part of Baltimore. The site is also large, allowing for various configurations and space for a wetland component.

Threats

The site is susceptible to sea level rise being close to the water and the site can be hazardous if the soil is not treated properly.

Figure 28: Sparrows Point Site Analysis. Diagram by Author.

A zoomed-out view of Sparrows Point shows a few roads traversing through the site while the highways are adjacent to it. Remnants of small older building are spread throughout the site while larger newer warehouses take up the north and the middle. The hexagon off to the West is Fort Carroll Oyster Sanctuary which would be a great view in terms of ecological restoration. While the whole site could use environmental restoration, a specific point located to the North West was chosen to be the demonstrator of ecological restoration by having direct access to the site. While the whole site and many parts of the bay need an intensive treatment, the list of places would be limitless.

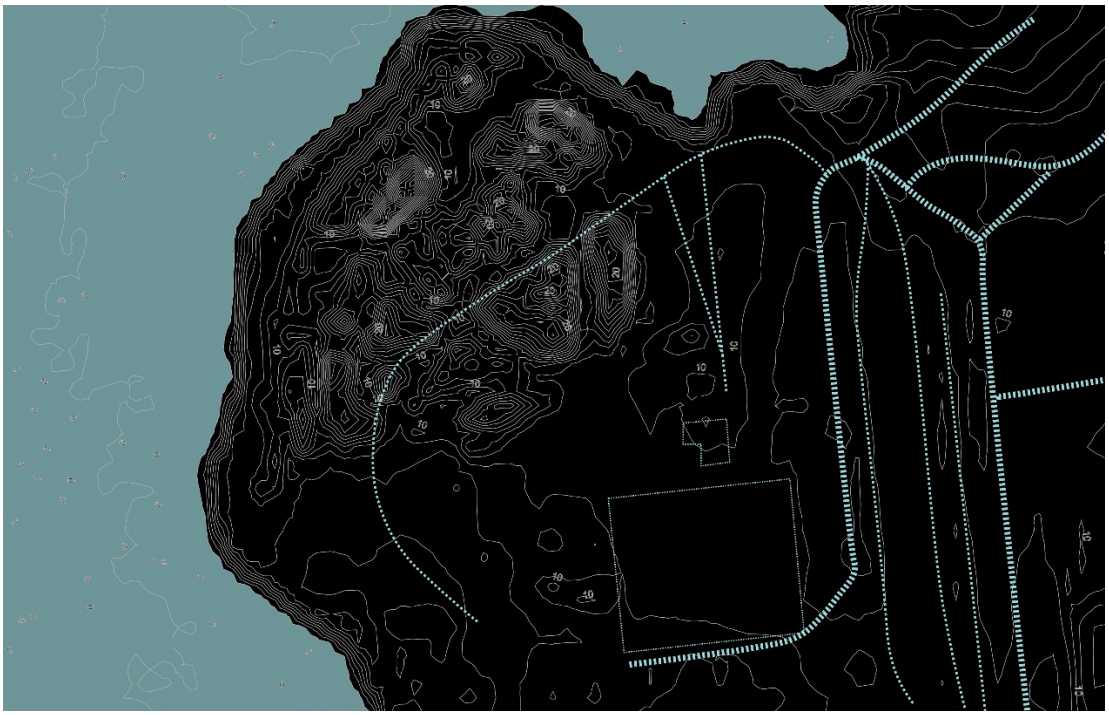

Figure 29: Sparrows Point Zoomed In Site Analysis. Diagram by Author.

Zooming into the specific portion of the site shows scars of buildings and roads that went through the site.

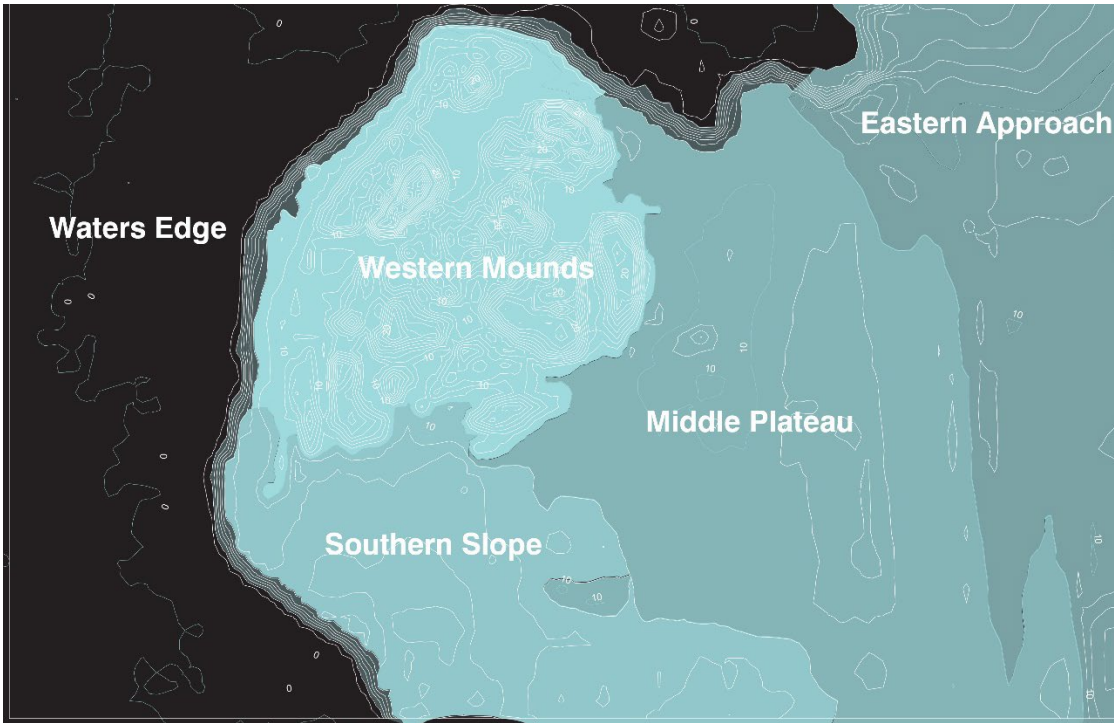

Figure 30: Sparrows Point Topography. Diagram by Author.

The site can be broken down to 4 main areas with the most important one being the western mounds that have a topography change of over 10 feet. Details are important, therefore understanding the context of Baltimore's restaurants is essential to planning the site.

Baltimore Seafood Overview

Baltimore is home to many types of seafood, with its most famous being crab cakes. Other fish, shellfish, and mainstream food chains exist here too. While fast food is very prominent, seafood is local to the area and not as replicable.

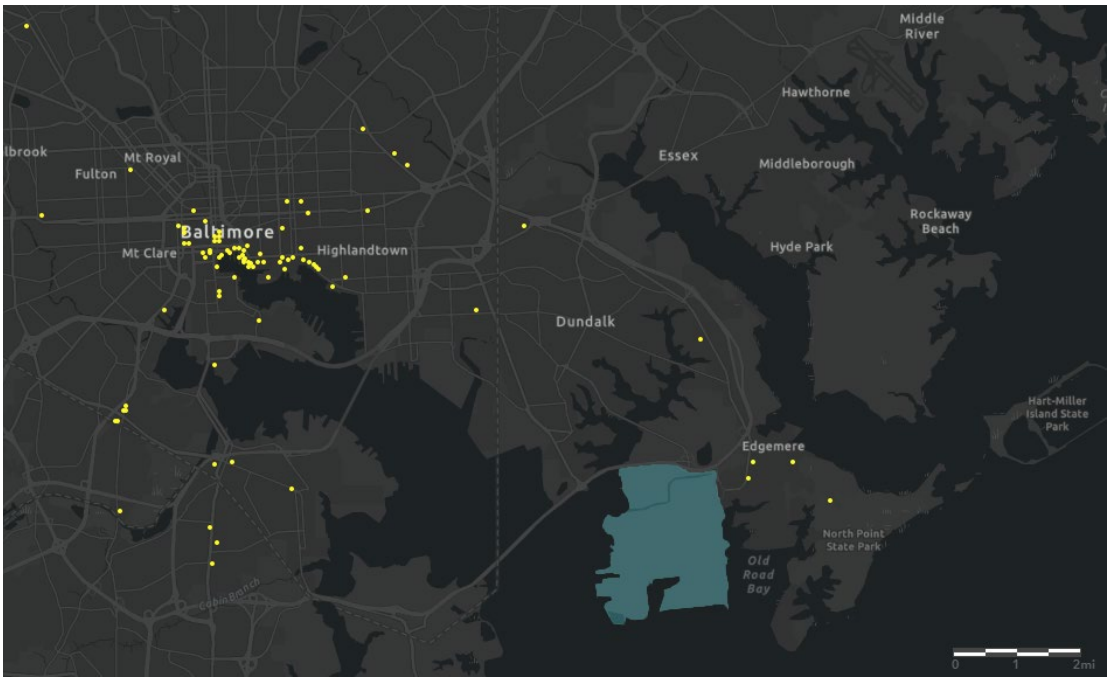

Figure 31: Distribution of Seafood Restaurants and Markets in Baltimore. Diagram by Author. Data from Google Maps

From the diagram, seafood is located at the heart of the harbor. The further away from the harbor, the scarcer seafood restaurants become. There are some by Sparrows Point and outside the city center. Restaurants generally are open from the

afternoon to 9pm. Away from the harbor, they are open earlier, but close around 6pm. Also, away from the harbor are seafood markets to distribute food further distances.

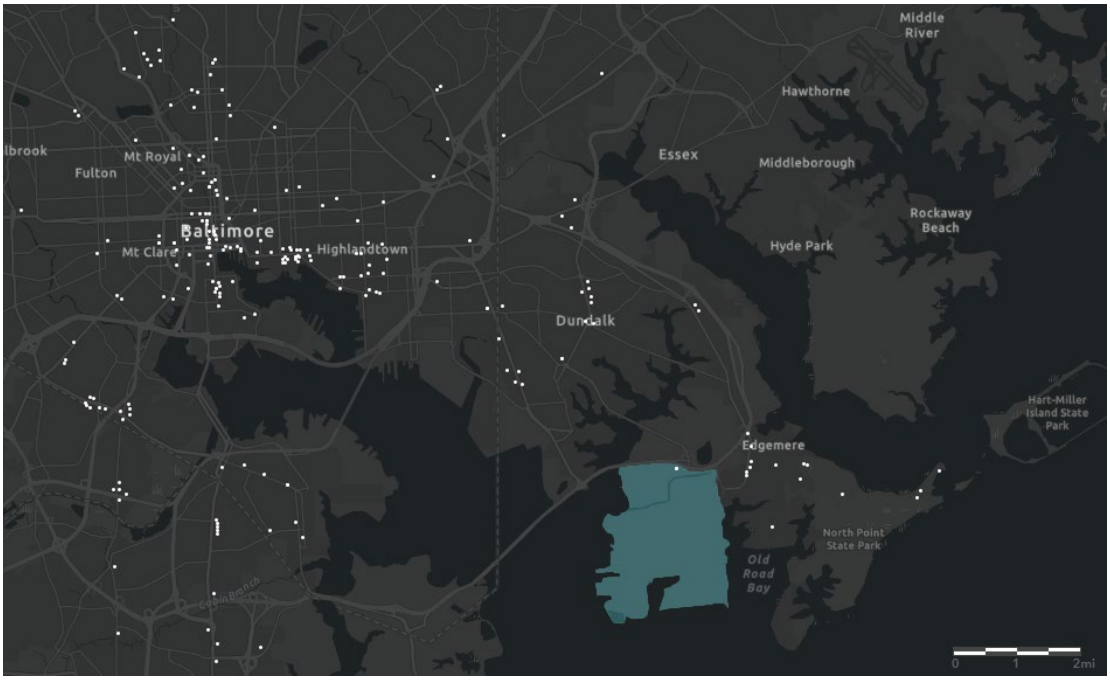

Figure 32: Distribution of Fast food (Burgers) in Baltimore. Diagram by Author. Data From Google Maps

In comparison to seafood restaurants, fast food and its replicability overtake the number of seafood restaurants. While not as dense as the seafood restaurants along the harbor, fast food is dense within the city and along major roads with intersecting highways. There is even a location at Sparrows Point. To further local cuisine furthers culture A local restaurant with a unique dining experience at the gates of the Patapsco would introduce Baltimore in an authentic and environmentally friendly way.

Precedents

With pollution, and food needing to be solved, many architectural precedents were explored. The result was a restaurant and wastewater treatment plant that could

be integrated to offer a solution to Sparrow's Point, rather than being individual entities.

Gross Square Footage: 7132 sq ft
Gross Circulation: 2829 sq ft
A: 1436 sqft
B: 1209 sqft
C: 207 sqft
Gross Seating: 1752 sq ft
Gross Bathroom: 386 sq ft
A (Public): 270 sqft
B (Employee): 116 sqft
Gross Admin/Lobby: 472 sq ft
A (Public): 58 sqft
B (Gathering): 413 sqft
Gross Kitchen: 789 sqft
A (Main Kitchen): 601 sqft
B (Secondary Prep): 188 sqft
Storage/ Other: 980 sq ft
A (Other Room): 322 sqft
B (Large Storage): 491 sqft
C (Electrical): 18 sqft
D (Cold Storage): 38 sqft
E (Secondary Storage): 75 sqft
F (Utility): 34 sqft

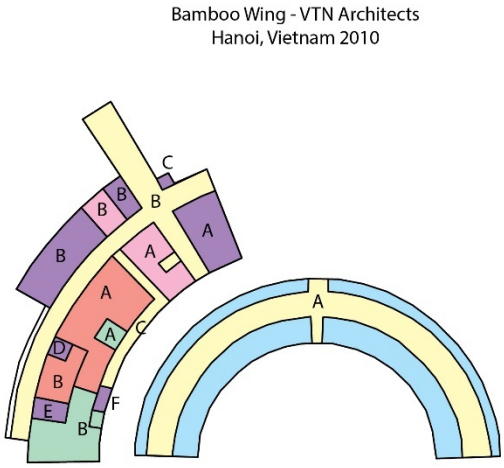

Figure 33: Program Tabulation of Bamboo Wing. Diagram by Author.

Bamboo Wing by VTN Architects in Hanoi, Vietnam, is a sustainable dining experience that integrates with nature. Being based on a bird's wing, the wing is 12 meters wide, balances on a single leg to create open space and shaped to provide natural ventilation and thermal comfort.[98] The seating area is adjacent to a lake where performances can take place. The lake and wing allow for cool air to travel through the curved space.

Integrating a dining experience with the water could parallel the experience at Sparrows point. By using only natural materials, bamboo, and natural ventilation, the connection with nature is increased. This would contrast the industrial setting of Sparrows Point and the rest of the Baltimore Harbor, but could be the model for

[98] VTN Architects, "Bamboo Wing," Accessed December 2020, https://www.vtnarchitects.net/restaurant-properties/bamboo-wing

environmental rejuvenation. Connections made by the restaurant would help educate the public while creating a reason to visit Sparrows Point, but the site needs to be cleaned to be a wholistic and safe experience.

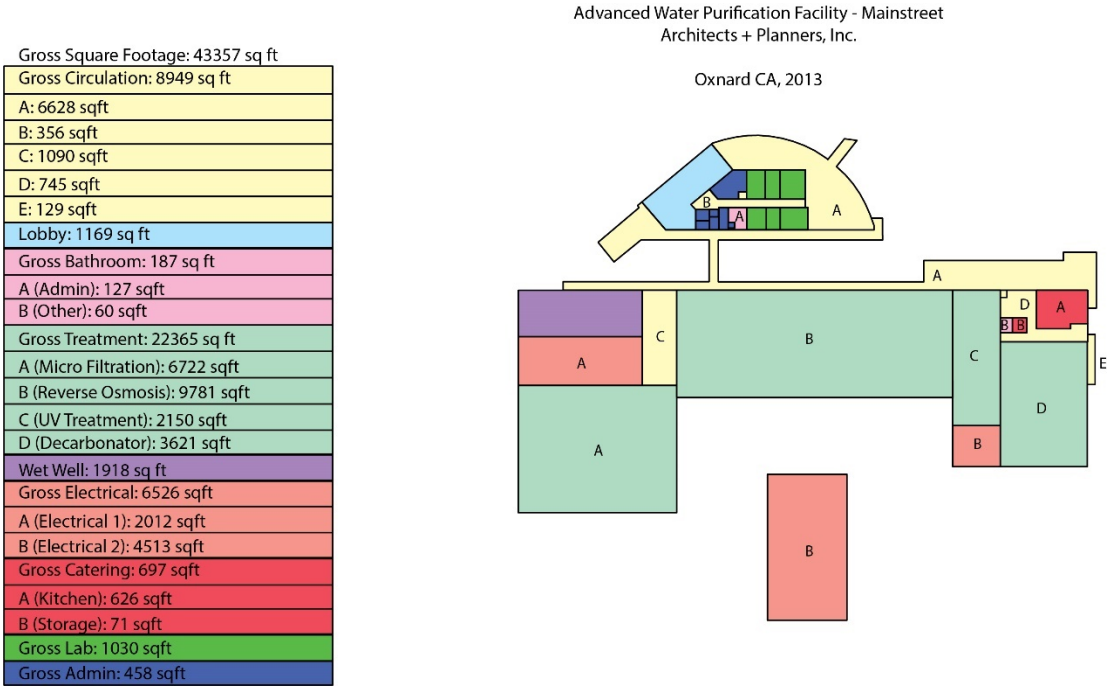

Figure 34: Program Tabulation of Oxnard Water Treatment Plant. Diagram by Author.

The Oxnard Advanced Water Purification Facility in California by Mainstreet Architects and Planners is a municipal building that offers an educational experience, an intensive water treatment system, and wetlands for demonstration and future capabilities. The building's sustainable systems include PV panels, reflective roofing for minimal heat gain, operable windows for passive ventilation, and the building layout to plan for expansion to clean 15 million gallons of water daily.[99] Circulation was important for the educational program to take place. The wetlands component

[99] Mainstreet Architects + Planners Inc, " Oxnard Water Division G.R.E.A.T. Program Administration Building," Accessed December 2020, https://www.mainstreetarchitects.com/urbandesign.

demonstrates the long-term solution and effects of how it can benefit the rest of California.

The Advanced Water Purification Facility (AWPF) works with the Groundwater Recovery Enhancement and Treatment (GREAT) program to recycle the city's water back for agricultural use with up to 123,000 cubic meters a day.[100] The water treatment program consists of microfiltration, reverse osmosis, ultraviolet disinfection, and advanced oxidation. It begins with chlorination of the effluent being pumped to the microfiltration chamber. Microfiltration removes pollutants such as coliform bacteria, Giardia, and Cryptosporidium.[101] The water travels to the Reverse Osmosis chamber where it passes through various membranes. Water here is combined with sulfuric acid to create concentrate, some that goes to the ocean with neutralizing chemicals and to the wetlands system, and water is recovered up to 80 to 85 percent.[102] Finally, water reaches the Ultraviolet and advanced oxidation process. Ultraviolet Light and Hydrogen peroxide react to each other, cleaning the waters. A UV system was chosen for its low energy use to offset California's high energy pricing of 15 cents per kilowatt hour.[103]

Post treatment involves the use of liquid lime to stabilize the UV effluent. Liquid Lime increases the pH, alkalinity, and calcium levels on top of acidification and carbon dioxide concentration.[104] Reverse Osmosis effluent goes to the wetlands

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[100] Jim Lozier, and Kim Ortega, "The Oxnard Advanced Water Purification Facility: Combining Indirect Potable Reuse with Reverse Osmosis Concentrate Beneficial Use to Ensure a California Community's Water Sustainability and Provide Coastal Wetlands Restoration," *Water Science and Technology : A Journal of the International Association on Water Pollution Research* 61, no. 5 (2010): 1158, doi:10.2166/wst.2010.027.
[101] Ibid., 1160.
[102] Ibid.
[103] Ibid., 1161.
[104] Ibid.

to prove certain plants can live and clean the water further. This is done at a smaller scale of the AWPF site to eventually increase scale to be more natural.

The AWPF and Bamboo Wing can create a wholistic and educational dining experience through their integration with the environment. AWPF cleans the water, enhances building performance through sustainable methods, and uses its wetland system for research. Bamboo Wing offers environmental comfort through is structure and connectivity to nature. Circulation in both projects empower the experience through learning and dining. What remains to complete the system and promote locality would be to have food be produced on site.

Chapter 7: Design Proposal

Site Design

Taking advantage of the square footage of the site is necessary for planning the maximum effectiveness of the landscape and architecture to create an engaging and educational experience. The Beijing Olympic Park wetlands was the precedent used to filter water on the site. The Beijing Olympic park wetlands reclaim water from the other event spaces and the rest of the northern park. The wetlands contain 3 areas: surface and subsurface wetlands, oxidation pond, and ecozone. The wetlands and ponds filter the water for the ecozone where the public and wildlife can experience clean water. This system will be an extension of the water treatment plant to educate the public on the natural processes that occur in the environment. A scalar plop of the Beijing Olympic Park wetlands was inserted and reconfigured for the initial planning of the site.

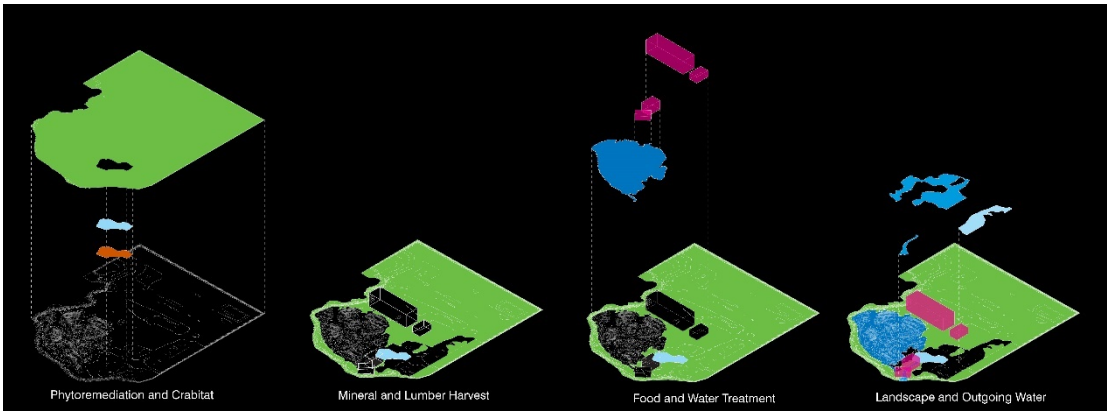

Figure 35: General Site Phasing. Diagram by Author

To use the site as a learning tool, the site remediation will be phased to educate the public on phytoremediation. The first phase involves marking the site with a crab habitat or crabitat to educate the public on the blue crab. The preceding

phases phytoremediate the site, clear portions for building materials, and construct the water treatment plant, wetlands, restaurant, and outflowing water. In the final phase, the crabitat can be integrated with the restaurant program.

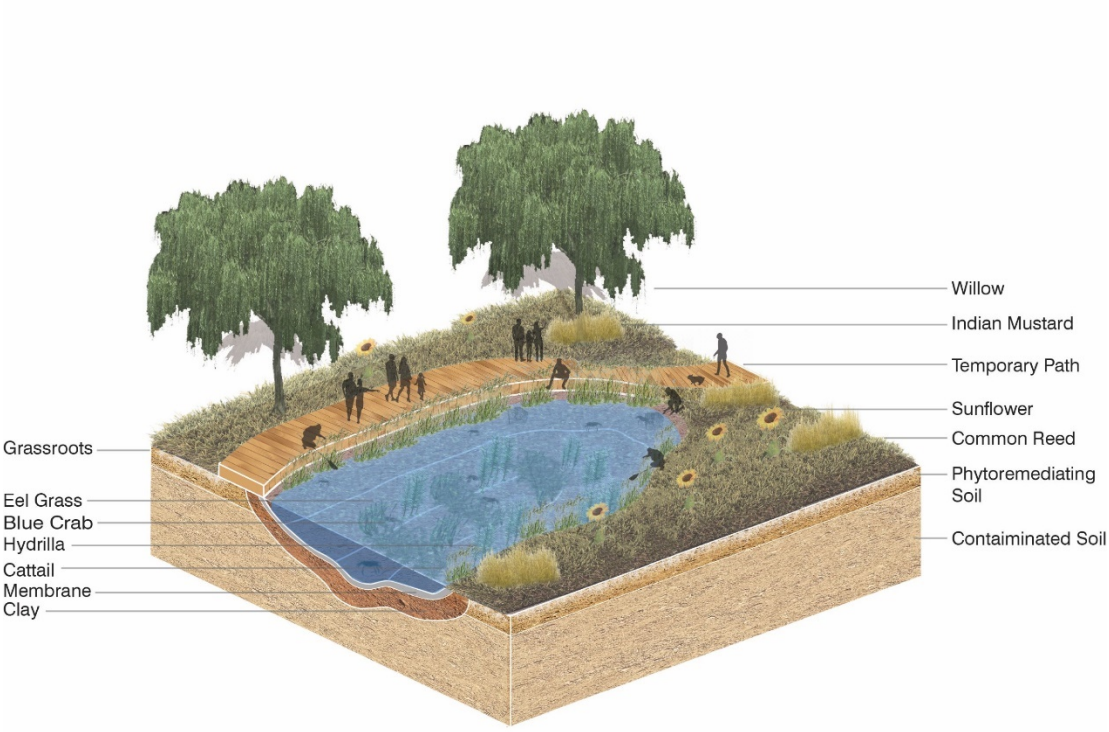

Figure 36: Crabitat Axon. Illustration by Author

This diagram shows the crabitat in the first phase of the site plan. It contains vegetation to clean the soils and a layer of clay to prevent contamination of the waters. The waters contain various types of submerged aquatic vegetation to shelter the crabs. Phasing helps visitors understand the site over time, therefore it is important to understand the context of the crabitat within the whole system.

Figure 37: Site Plan. Illustration by Author

The diagram above details the layout of Sparrows Point once all the phased cleanup effort has been completed. Visitors enter from the East where they go from parking to either the water treatment, wetlands, or can go directly to the restaurant. There are two crabitats, an isolated and integrated one within the wetlands system. The integrated one is to be the result of a clean water system while the other continues as the site marker. While the crabitat characterizes the site the most, it is essential for the visitors to experience the entire site.

Figure 38: NW to SE Site Section. Illustration by Author

The site section characterizes the site from the wetlands to the water treatment plant, to the parking. The wetlands topography varies showing the mounds that people can

stand on to view the ecological forces at play. The water treatment plan and parking areas are flat.

Figure 39: SW to NE Site Section. Illustration by Author

The restaurant topography slowly rises to the wetlands. Understanding the physical conditions of the site are necessary to inform the experience. Before reaching the restaurant, the visitors can experience the landscape if they would like to learn about the wetlands system or become immersed before eating.

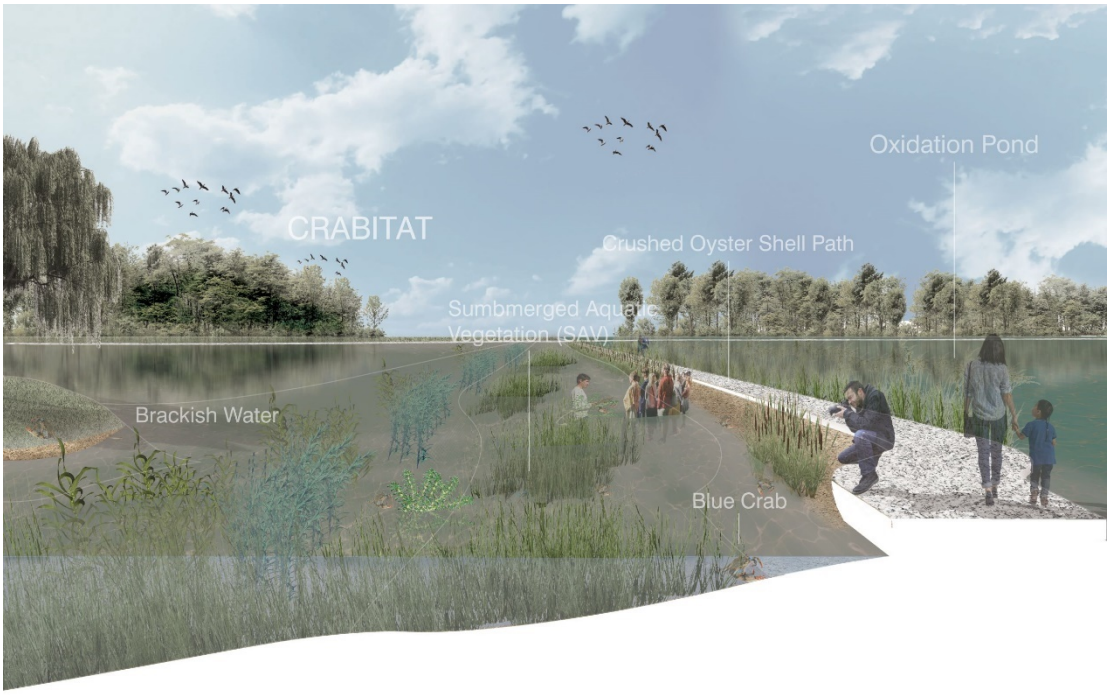

Figure 40: Crabitat Perspective. Illustration by Author

The complete crabitat draws people along the oxidation pond where they can observe the Blue Crab.

Figure 41: Oxidation Pond Perspective. Illustration by Author

The oxidation pond contains paths to walk alongside the flow of water.

Figure 42: Bridge Perspective. Illustration by Author

Preceding the oxidation pond are the wetlands. The wetlands is a large area requiring crossings for visitors to travel. These bridges let people get closer to the water.

Figure 43: Island Perspective. Illustration by Author

The wetlands islands serve as a park where visitors walk along the wetlands, observing natural systems and processes.

Figure 44: Ecozone Perspective. Illustration by Author

Wrapping back to the ecozone, visitors can experience the wildlife and fully functioning ecologies at the end of the wetlands sequence. The impact of this zone displays the magnitude of clean water.

Figure 45: Loading Road Perspective. Illustration by Author

Finally, the loading road protects the wetlands from sea level rise while offering views of the Chesapeake as one approaches the restaurant from this route.

The components of the wetlands system are essential for the public to understand the effect of cleaning the water. With the crabitats as a place to rejuvenate the crab population and double as a food source, the impact of environmental rejuvenation can be comprehended at the restaurant.

Building Design

The purpose of the restaurant is to act as an extension of the landscape. Many precedents involving architecture, water, and space were studied to understand the impact of being above, in, and below water. Architects like Tadao Ando and VTN

Architects have their projects varying the experiences around water. This building celebrates the cleaning of the water flowing out to the bay, rejuvenating its waters.

Figure 46: Bird's Eye View. Illustration by Author

The restaurant, located in the South West of the wetlands, acts as an extension of the landscape while celebrating the clean water. From the ecozone, water flows from the East, through the building, and out to the Bay on the West. The primary building materials used were ferrock, limewash, willow, CLT panels, and Glulam beams and columns. Ferrock is a replacement for concrete where iron powder, crushed glass, and carbon dioxide are combined to create a mix that is stronger and does not contaminate when encountering water. Limewash coating comes from smaller plants during the phytoremediation stages where they precipitate calcite. This material acts as the transition between interior and exterior. Willow is used as a façade material from the phytoremediation stages to create a dynamic and organic façade that reflects the blue crab. CLT and Glulam are combined for the structure of

the building, continuing the use of wood for a natural and engaging experience.

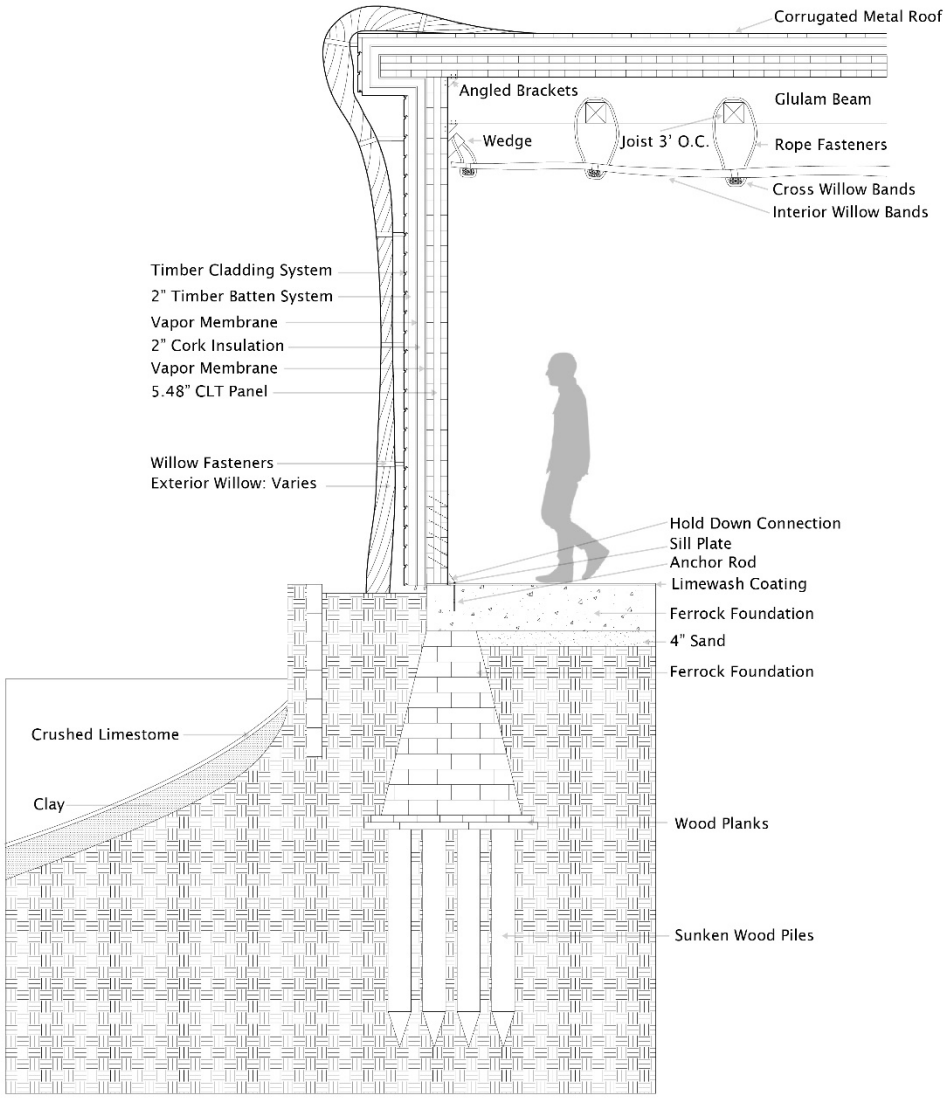

Figure 47: Wall Section. Illustration by Author

The wall section depicts how the CLT meets the ferrock. The ferrock foundation is based on the foundations in Venice since they both encounter large amounts of water. A ferrock divider is placed separating the dirt from the water to give the willow ample place to grow. Willow on the inside is hung from the battens and wedge to provide space to step upwards.

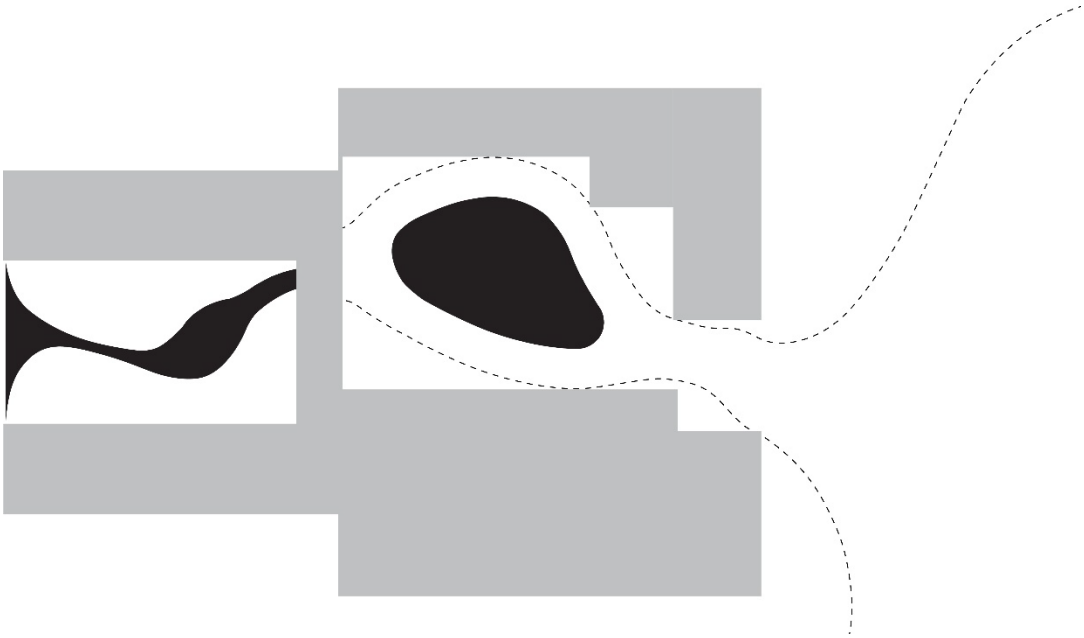

Figure 48: Parti. Diagram by Author

The parti of the building dictates how a translation of the topography cuts through the building. The oyster form dictates the center of the building since the oyster is a significant element of the bay where it filters water. All the spaces push away from the oyster based on the topography lines. On the left side, the dining area continues the topography, but the topography is confined to the building's spaces. Water continues through this space out to the bay.

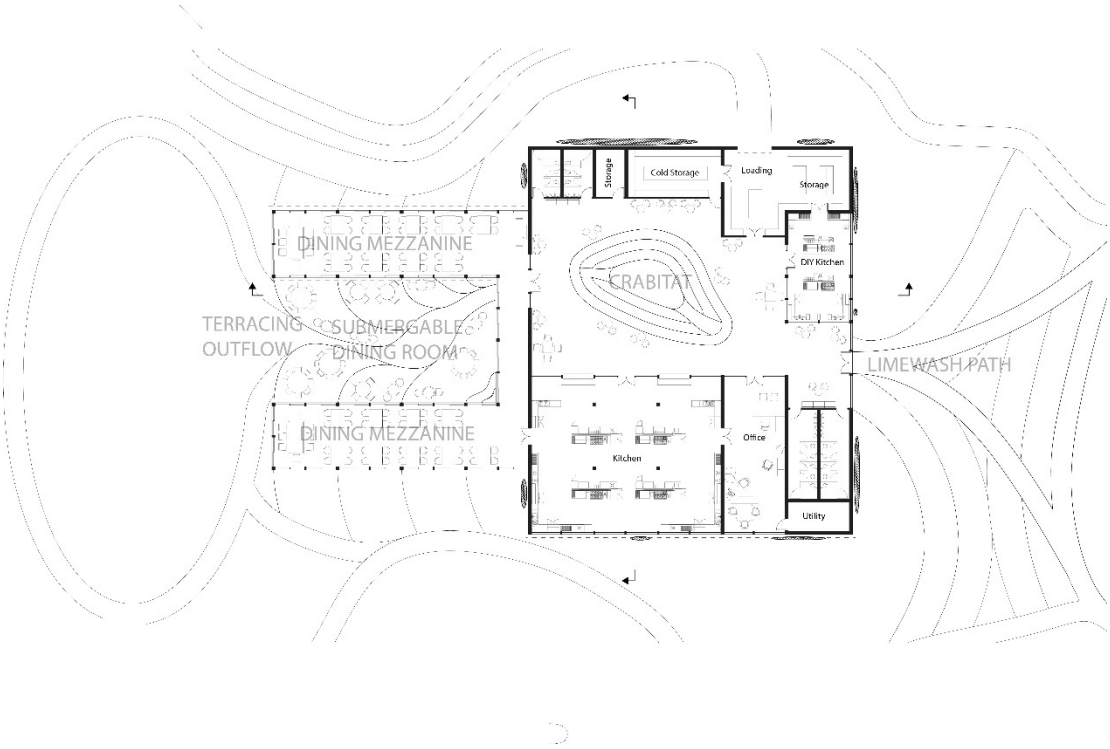

Figure 49: Floor Plan. Illustration by Author

As visitors enter from the limewash path on the exterior, they travel to the center of the restaurant; the crabitat. The crabitat contains water flowing through the space where visitors can catch their dinner. From there, visitors can go to the DIY kitchen to learn how to prepare their meal. The visitors can also sit within the crabitat depending on the water level. Around the crabitat contains seating for a smaller café experience. Once the visitors have ordered, they can continue to the dining mezzanine for a controlled dining experience, but more adventurous visitors can sit within the submergible dining room where water can flow through and flood the space while

flowing out to the bay.

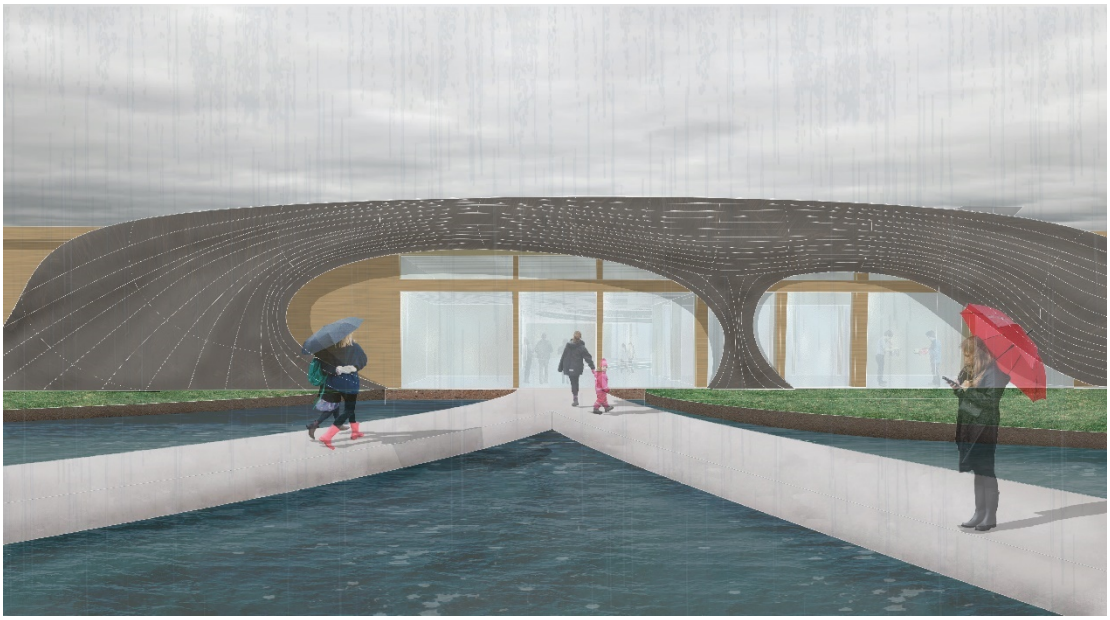

Figure 50: Rainy Entry Perspective. Illustration by Author

The approach draws people to the building over the water. The façade thickens and thins, becoming more and less protective of its interior spaces while balancing the views to the outside.

Figure 51: Entry Perspective Day. Illustration by Author

When willow is planted, it can grow, creating a sense of dynamism on the façade.

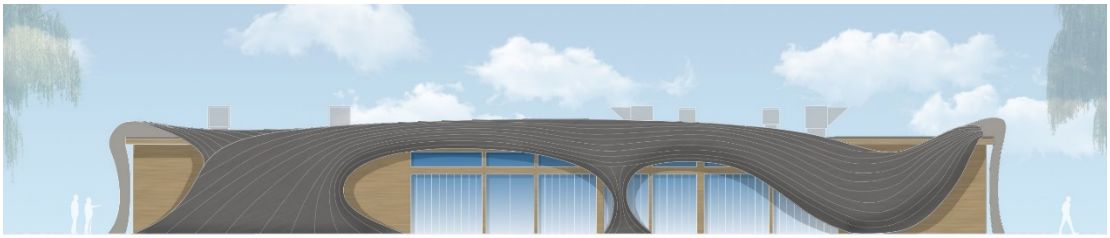

Figure 52: East Elevation. Illustration by Author

The elevations wrap up from right to left to mimic the bouligand or helix structure of the crab chitin fibers.

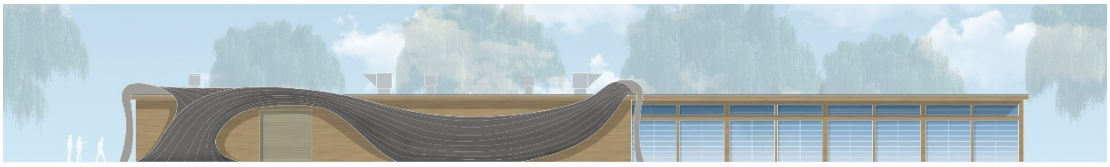

Figure 53: North Elevation. Illustration by Author

The willow thickens around the cold storage, bathrooms and regular storage, but opens by the loading door.

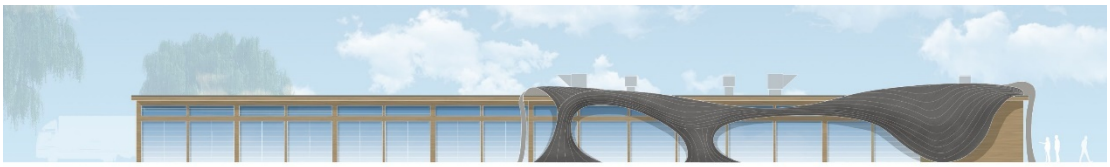

Figure 54: South Elevation. Illustration by Author

Willow past the elevation wraps up to block the views of the mechanical equipment when approaching the building.

Figure 55: West Elevation. Illustration by Author

The willow on the West elevation looks like it covers the dining mezzanine but does not to distinguish the two areas.

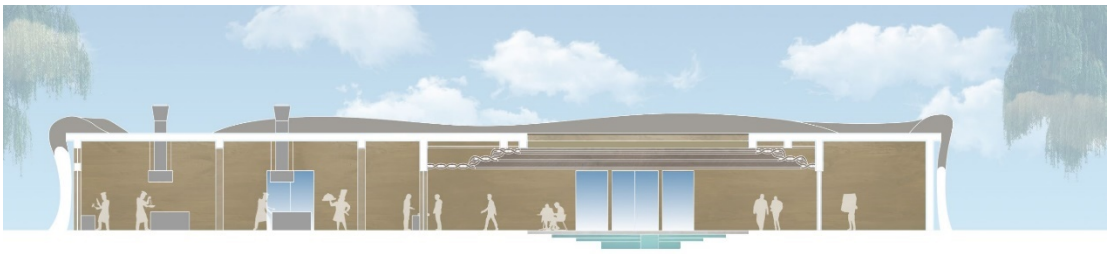

Figure 56: Cross Section. Illustration by Author

In the section, willow steps up while the ferrock steps down. The kitchen spaces on the left connect to the crabitat where people can order and eat in the dining mezzanine or the crabitat. On the right, cold storage is located to connect to the loading bay.

Figure 57: Longitudinal Section. Illustration by Author

In the longitudinal section, water from the landscape steps down from the wetlands landscape through the building to the bay.

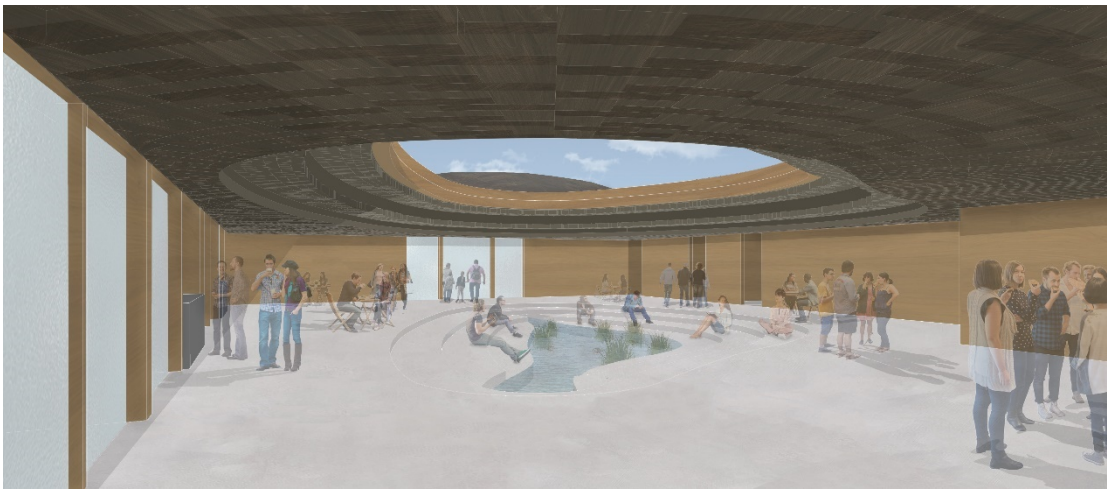

Figure 58: Interior Crabitat Day. Illustration by Author

As visitors traverse the interior, willow steps up in the interior signifying the layers of the crab and oyster shell. The oyster steps down where people can rest by the flowing water.

Figure 59: Interior Crabitat Rain. Illustration by Author

When it rains and the water level is high, the space within the crabitat changes. People are unable to sit in the previous shallow space and can continue to the dining mezzanine.

Figure 60: Dining Mezzanine Section Perspective Day. Illustration by Author

When the water level is low, the dining mezzanine and submergible dining room offer two unique experiences. On the interior, willow steps up, directing the view out toward the bay and Fort Carroll Oyster Sanctuary. In between the mezzanines sit the submergible dining room that terraces downwards to the bay. This space is up close to the water for the more adventurous visitors.

Figure 61: Dining Mezzanine Section Perspective Rainy. Illustration by Author

During high tide and inclement weather, the water level will rise above the terraces, flooding the dining room. While it is a reduction of space, it is about the celebration of water in conjunction with nature taking control.

Chapter 8: Conclusion

Moving Forward

The Chesapeake Bay is a home to various ecologies and ecological systems. While humanity makes efforts to restore the bay, larger entities continue to pollute at a rate faster than we can restore. While the public has a baseline standard of pollution being bad, having a deeper understanding of taking care of the environment can strengthen their viewpoint and spread awareness of the issue. A strengthened viewpoint can increase their desire for a cleaner environment once they know what can come from it. This thesis demonstrates an example of environmental restoration through using architecture as an extension of a landscape system. Its immersion of dining can strengthen the desire of cleaner "natural" spaces amidst a recovering Bay.

While this thesis proposes an ecological system with architecture being the culmination and celebration of the benefits of the system, a wetlands and restaurant are not the only ways to remediate a space, nor the only solution to enjoy the benefits of the environment. A balance between what the public could learn and what environmental problem needs to be solved should be the drivers for restoring different parts of the Bay. While the Blue Crab acts as a mediator between landscape, architecture, and one's stomach, there many other species that have struggling populations that could be cared for.

Humanity has been disconnected from the environment for a long time. While it is our fault, it is our responsibility to restore those connections. By taking accountability through ecological restoration, aquaculture, architecture, and time, our separation will no longer exist. The deeper we understand the environment, the closer

we become. The closer we become, the association between humanity and nature will become synonymous. And caring for the environment will be a part of our nature.

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